

**“SOIL FERTILITY STATUS OF PADDY AND SUGARCANE
GROWING AREAS OF VILLAGE BUTLAW AND DABHALIA
OF NAVSARI DISTRICT”**

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IN
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***MY BELOVED PARENTS, from whom I hereditary
the interest in **SCIENCE*****

***MY RESEARCH GUIDE, who lead me to provide
this proof of **SCIENCE*****





ABSTRACT



**“SOIL FERTILITY STATUS OF PADDY AND SUGARCANE
GROWING AREAS OF VILLAGE BUTLAW AND DABHALIA
OF NAVSARI DISTRICT”**

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A B S T R A C T

The present investigation was carried out with an objective of soil fertility evaluation of the village Butlaw and Dabhalia in Navsari district of Gujarat, where characterization of natural resources *viz.* soil, climate, water and vegetation was done along with crop suitability evaluation. Three representative profiles were excavated in the study area based on the land use and topography. Profiles were studied, interpreted and then sampled horizon-wise as per standard procedure (Soil Survey Staff, 2006). From the each representative profile area, grid point based surface (0-20cm) and sub-surface (20-40cm) soil sampling was done from hundred and two locations with the help of GPS. All the surface and sub-surface samples were analyzed for pH, EC, SOC, CEC, ESP, available N, P₂O₅, K₂O, S, Fe, Mn, Cu and Zn. Profile samples were analyzed for soil colour, texture, structure, consistency, field capacity, permanent wilting point, available water capacity, bulk density, particle density, porosity, water stable aggregates and associated parameters along with all the above physico-chemical parameters and available nutrients including E_{Ce} and free CaCO₃. All the data were processed in GIS to generate the spatial distribution of physico-chemical parameters and available nutrients in the surface

soils of the study area. In order to characterize the climatic parameters viz., rainfall, temperature, relative humidity, sunshine hours and wind velocity, daily data for past 30 years (1987 to 2016) were obtained from Department of Meteorology, N. M. College of Agriculture, NAU, Navsari and parameter wise analysis was done. Ground water samples were collected from the 30 locations during pre and post monsoon seasons and analysis was done for pH, EC, SAR and RSC. Land use patterns was recorded and soil-site suitability evaluation was done for the most common crops of the area i.e., paddy and sugarcane.

All the profiles were classified up to family level, where temperature regime is hyperthermic and texture was fine to very fine with montmorillonite. Up to the sub group level profile 1 (Western part of Butlaw village) and 2 (Eastern part of Butlaw and Dabhalia village) were classified as *Typic Haplusterts*, while profile 3 (Western part of Dabhalia village) was classified as *Typic Haplustepts*. The depth of all profiles were more than 110 cm indicating that soils of the study area were deep, which is a good sign for optimum plant growth of paddy, sugarcane as well as for other crops. Soil colour of the different horizons in all the profiles were observed very dark grayish brown (10YR 3/2) to yellowish brown (10YR 5/4).

The sand, silt and clay content (< 2 mm soil) of different horizons were ranged from 8.84 to 35.56, 18.4 to 32.52 and 45.27 to 69.45 per cent, respectively in all profiles. BD and PD of the different horizons in all the profiles were varied from 1.32 to 1.51 and 2.55 to 2.63 Mg m⁻³, respectively. Porosity of the different horizons in all the profiles was varied from 42.15 to 49.61 per cent.

Water stable aggregate >1.0 mm and between 0.5 to 1.0 mm size of the different horizons in all profiles were varied widely from 7.16 to 27.82 and 15.72 to 32.66 per cent, respectively. Available water capacity of the different horizons in all the profiles was varied from 7.58 to 14.94 per cent.

In general $\text{pH}_{(1:2.5)}$ of the different horizons in all the profiles was varied from 7.62 to 8.75. ECe of the different horizons in all the profiles was varied from 0.51 to 2.29 dS m^{-1} . CEC of the different horizons in all the profiles was varied from 38.9 to 47.87 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$. ESP of the different horizons in all the profiles was varied from 0.93 to 5.47 per cent. CaCO_3 of the different horizons in all the profiles varied from 0.61 to 1.68 per cent.

OC content of the different horizons in all the profiles was varied from 0.15 to 1.83 per cent. Available N, P_2O_5 , and K_2O of the different horizons in all profiles were varied widely from 20 to 143, 4 to 152 and 259 to 134 kg ha^{-1} , respectively. Available S of the different horizons in all the profiles was varied from 12 to 197 mg kg^{-1} . Available Fe, Mn, Zn, and Cu of the different horizons in all the profiles were varied from 3.51 to 65.19, 3.61 to 24.39, 0.24 to 0.99 and 0.84 to 7.36 mg kg^{-1} , respectively. A general decreasing trend of all available nutrients was reported with increasing soil depth in all the profiles.

In the entire study area, 76.47 and 23.53 per cent surface soil samples were reported as normal and slightly alkaline in nature. While 17.65, 78.43, 3.92 per cent sub-surface soils were reported as normal, slightly alkaline and moderately alkaline in nature, respectively. From the salinity point of view 100 per cent surface as well as sub-surface soil samples were reported as non saline in

nature. Over 99 per cent surface and sub-surface soil samples were also recorded as non sodic in nature. CEC of surface and sub-surface soils of the study area was found varied from 33.75 to 51.66 and 39.13 to 61.20 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$, respectively.

In general 8.74 and 91.26 per cent surface soil samples of the study area were found as medium and low in OC content, while 7.32, 22.49 and 70.19 per cent sub-surface soil samples were found as low, medium and high in OC content, respectively. Available N content of 54.16 and 45.84 per cent surface soil samples were classified into low and medium class, while 100 per cent sub-surface soil samples were classified into low class. Available P_2O_5 content of 5.12 and 94.88 per cent surface soil samples were classified into medium and high class, while 7.25 and 92.75 per cent sub-surface soil samples were classified into medium and high class. Available K_2O content of 35.41 and 64.59 per cent surface soil samples were classified into medium and high class, while 68.06 and 31.94 per cent sub-surface soil samples were classified into medium and high class. Available S content of 18.02 and 81.98 per cent surface soil samples were classified into medium and high class, while 7.07, 35.39 and 57.54 per cent sub-surface soil samples were classified into low, medium and high class. 100 per cent surface as well as sub-surface soil samples were classified into sufficient class in the case of available Fe, Mn and Cu. Available Zn content of 36.15 and 63.85 per cent surface soil samples were classified into marginal and sufficient class, while 14.14, 61.25 and 24.61 per cent sub-surface soil samples were classified into deficient, marginal and sufficient class, respectively.

Climate of selected study area is sub-humid and receiving about 1623 mm rainfall annually in 50 rainy days. Highest rainfall was observed in July (38.54%) followed by August (21.22%) and June (19.88%). South-West monsoon was reported to contribute about 97 per cent of the total rainfall. Lowest mean monthly minimum temperature was observed in January (13.02°C) and the highest mean monthly minimum temperature was observed in June (26.58°C). Lowest mean monthly maximum temperature is observed in August (29.89°C) and the highest mean monthly maximum temperature is observed in April (35.14°C). Highest relative humidity in the morning was observed in the month of September (91.63 %) and lowest humidity is observed in the month of February (78.14 %). Highest relative humidity in the evening was observed in the month of July (81.07 %) and lowest humidity is observed in the month of February (33.89 %). The monthly mean value of sunshine hours was observed varying between 3.26 hours in July to 9.99 hours in April and May with an annual mean of 7.80 hrs. Wind velocity was recorded ranging from 2.56 km hr⁻¹ during November to 9.09 km hr⁻¹ during June with the annual average wind velocity of 5.09 km hr⁻¹.

In the study area the major source of irrigation water is canal water, received from Navsari branch of Kakrapar left bank canal. Farmers are also using ground water where canal water irrigation is not possible (25% area). The pH of ground water was recorded ranging from 7.25 to 7.81 with a mean of 7.51 in the pre monsoon season. While, the pH of post monsoon ground water was recorded ranging from 7.17 to 7.67 with a mean of 7.40. All the water samples were reported as alkaline in nature. EC of ground water

was recorded ranging from 0.84 dS m^{-1} to 1.31 dS m^{-1} with a mean of 1.02 dS m^{-1} in the pre monsoon season. While, in the post monsoon season the EC was recorded ranging from 0.77 dS m^{-1} to 1.22 dS m^{-1} with a mean of 0.93 dS m^{-1} . All the water samples were classified into C_3 (High salinity hazard) class based on EC values. SAR was recorded ranging from 2.25 to 5.71 with a mean of 4.26 in the pre monsoon season. While in the post monsoon season it was recorded ranging from 1.27 to 3.74 with a mean of 2.59. All the water samples were classified into S_1 (Low sodium hazard) class based on SAR values. Based on the RSC values, 63.33 and 36.67 per cent pre monsoon ground water samples were classified into S (suitable) and MS (moderately suitable) class. While in the post monsoon season 70 and 30 per cent samples were classified into suitable and moderately suitable class.

Abundant natural vegetation is existing in the study area are *Phoenix sylvestris*, *Acacia nilotica*, etc. of common occurrence. Diversified weed flora is observed in the study area, which causes considerable losses in crop production.

Paddy, Sugarcane, Spider Lili, Mango and Sapota were the predominant crops grown in the selected study area. From the land use point of view 49, 34, 17 and 10 per cent area were found occupied by Paddy, Sugarcane, Spider Lili and Mango+Sapota, respectively.

Profile 2 is evaluated as highly suitable (S_1), while profile 1 and 3 are evaluated as moderately suitable (S_2) for paddy crop cultivation. In relation to sugarcane crop profile 3, 2 and 1 are evaluated as highly suitable (S_1), moderately suitable (S_1) and marginally suitable (S_3) for cultivation, respectively.

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C E R T I F I C A T E

This is to certify that the thesis entitled, “**SOIL FERTILITY STATUS OF PADDY AND SUGARCANE GROWING AREAS OF VILLAGE BUTLAW AND DABHALIA OF NAVSARI DISTRICT**” submitted by **SOURAV CHOUDHURY** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** of the **Navsari Agricultural University** is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Navsari

(J. M. Patel)

Date: / /2017

Major Advisor



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D E C L A R A T I O N

This is to declare that the whole of the research work reported here in this thesis for partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** by the undersigned is the result of investigation done by me under the direct guidance and supervision of **Dr. J. M. Patel**, Associate Research Scientist, Soil and Water Management Research Unit, Navsari Agricultural University, Navsari and no part of the work has been submitted for any other degree so far.

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Place: Navsari

Date: / /2017

(Sourav Choudhury)

SYMBOLS AND ABBREVIATIONS



LIST OF SYMBOLS AND ABBREVIATIONS

Symbols

=	: Is equal to
X	: Multiply
-	: Minus
-1	: Per
+	: Plus
;	: Semi colon
%	: Per cent
&	: And
<	: Less than
>	: More than

Abbreviations

<i>Anon.</i> ,	: Anonymous
AWC	: Available water capacity
BD	: Bulk density
°C	: Degree Celsius
cm	: Centimeter
Ca	: Calcium
CEC	: Cation Exchange Capacity
Cu	: Copper
cmol(p ⁺)kg ⁻¹	: Centimol positive ion per kilogram
dS m ⁻¹	: Desi Simen per meter
DTPA	: Diethylene Triamine Penta Acetic Acid
EC _(1:2.5)	: Electrical Conductivity of _(1:2.5) soil and water
ECe	: Electrical Conductivity of Saturated Extract
ESP	: Exchangeable Sodium Percent
<i>et al.</i>	: Et alii (and others)
<i>etc.</i>	: Et cetera (and so on)
Fig.	: Figure
ft	: Feet
g	: Gram
g kg ⁻¹	: Gram per kilogram
GIS	: Geographical Information System
GPS	: Global Positioning System
GW	: Ground water

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ha	: Hectare
Hrs	: Hours
<i>i.e.</i> ,	: that is
K	: Potassium
Kg	: Kilogram
Kg ha ⁻¹	: Kilogram per hectare
Km	: Kilometer
K ₂ O	: Potassium oxide
Max.	: Maximum
Min.	: Minimum
mg	: Milligram
mg kg ⁻¹	: Miligram per kilogram
mg l ⁻¹	: Miligram per liter
m	: Meter
Me l ⁻¹	: Miliequivalent per litre
Mg	: Magnesium
Mn	: Manganese
mm	: Millimeter
MWD	: Mean Weight Diameter
NAU	: Navsari Agricultural University
NMCA	: Navinchandra Mafatlal College of Agriculture
N	: Nitrogen
No.	: Number
OC	: Organic carbon
P	: Phosphorus
pH _(1:2.5)	: pH of 1:2.5 soil and water extract
PD	: Particle density
P ₂ O ₅	: Phosphorus pentaoxide
ppm	: Parts Per Million
RDF	: Recommended Dose of Fertilizer
RH	: Relative Humidity
RSC	: Residual Sodium Carbonate
S	: Sulphur
SAR	: Sodium Absorption Ratio
SOC	: Soil Organic Carbon
<i>viz.</i>	: Videlicet (Namely)
WSA	: Water Stable Aggregates
Zn	: Zinc

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INTRODUCTION



I. INTRODUCTION

Soil is the most vital and precious natural resource that sustains life on the earth. The cropped area in India is limited and shrinking, whereas human and animal populations are increasing, resulting in fast decline in per capita arable land. The per capita availability of agricultural land has declined from 0.32 ha in 1950 to 0.14 ha in 2010 and will be further reduced to 0.10 ha by 2025 (Singh, 2010). So, the only way to increase agricultural production is to increase productivity of the currently shrinking and deteriorating soil resource.

Soil is a finite natural resource for agriculture. The native ability of soils to supply sufficient nutrients has decreased with higher plant productivity levels associated with increased human demand for food. Therefore, one of the greatest challenges today is to develop and implement soil, crop and nutrients management technologies that enhance the plant productivity and the quality of soil, water and air. If we do not improve the productive capacity of our fragile soils, we cannot continue to support the food and fibre demands of our growing population.

Present day exploitive agriculture, which involved efforts to increase crop yield has not only depleted the nutrient reserve of soils, but also resulted in the emergence of a number of new nutrient deficiencies. The indiscriminate use of irrigation and fertilizers over a period of time has resulted in imbalance of nutrients and deficiency of nutrients like sulphur and zinc in many soils.

Crop production broadly depends on the fertility of the soil where a crop is raised. The kind and quality of seed, climate of the region, soil moisture regime and plant protection measures adopted by a farmer are some other factor which affect the volume of production. But even if all these factors of crop production are in their optimum, the fertility of the soil largely determines the ultimate yield.

The fertility of soil is “its ability to provide nutrients for growth of plants, when other important growth factors are favorable”. For optimum crop production, a soil that enables deep rooting, provides aeration, has a good water holding capacity and consists of an adequate and balanced supply of plant nutrients is considered productive and fertile. Soil fertility is one of the most important factors in relation to evaluation of productivity status of the soils of an area of any region. It is also an important aspect in context of sustainable agriculture production.

Soil fertility must be periodically estimated as there is continuous removal of macro and micro nutrients by the crop intensively grown in every crop season. Soil fertility evaluation involves the estimation of the nutrient supplying power of a soil. A proper evaluation of the fertility of a soil before planting a crop helps in adopting appropriate measures to make up for the shortcomings and ensuring a good crop production. Out of several diagnostic techniques of fertility evaluation, soil testing provides the most accurate information about the fertility and productivity of the soils (Dhanke and Olsen, 1990) and is beneficial to formulate specific fertilizer

recommendations to various crops (Sood *et al.*, 2003). The declining soil fertility status is the main cause for low productivity of land. Therefore soil characterization in relation to evaluation of fertility status of the soils of an area or region is an important aspect in the context of sustainable production. For sustainability of the present agricultural system and management of our soil resources, a spatial data base regarding the fertility status of soils is required.

The general idea of fertility status, taking district as a unit has been worked out for major part of India. However, studying the fertility status of larger areas is often misleading. Hence assessing the fertility status and mapping at village level will be of greater importance for nutrient management with better precision on a sustainable basis (Sen *et al.*, 2008).

Evaluation of soil fertility status aimed to classify soil fertility based on a combination of several soil properties. Soil fertility status mapping is an important step in improving agricultural system planning as it integrates land resource characteristics and the needs of plants in every site and time.

Availability of reliable soil fertility map is the bottleneck for providing spatial fertilizer recommendation. If such maps are made available it is possible to transform the fertilizer equations into spatial fertilizer recommendation maps. The recommendations can be obtained by an extension agent or farmer simply by locating his area on map. The soil fertility maps can be linked with the various parameters to yield a recommendation map. A farmer can find out from such map the correct amount of fertilizer for potential yield. Such

maps can also be constructed for different yield levels. Preparation of reliable soil fertility map is a difficult task. The variability in fertility caused by application of fertilizers in individual farms is one factor that is difficult to account.

Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils to realize good crop yields. Obviously, a soil fertility map for a particular area can prove highly beneficial in guiding the farmers, manufacturers and planners in ascertaining the requirement of various fertilizers in a season or year and making projections for increased requirement based on cropping pattern and intensity.

Keeping these aspects in view, the present study was taken up in Butlaw and Dabhalia villages of Navsari taluka in Navsari district of Gujarat. The village mainly consisted of black soils, which are being intensively cultivated with high yielding crops like paddy and sugarcane, which require ample supply of irrigation water and nutrients. Since the information on systematic characterization and fertility classification of the soils of study area is lacking, an attempt was made with the following objectives.

Objectives:

- 1) To assess the physical and chemical properties of surface, sub-surface soil.
- 2) To assess the quality of irrigation water.
- 3) To know nutrient index of the different soil fertility.
- 4) To workout the correlation of the different properties of the soil.
- 5) Preparation of soil fertility maps.

REVIEW OF LITERATURE



II. REVIEW OF LITERATURE

Soil is a medium for plant growth and development and its productivity depends on several factors among which soil fertility is a major one showing direct relation with the crop yields, provided other factors are at optimum level. Soil fertility must be periodically estimated as there is continuous removal of nutrients by intensively grown crops in every season. Continuous cropping without adequate supply of essential nutrients poses a threat of nutrient deficiency in due course. The productivity of soil depends equally on its physical properties and the nutrient supplying power.

A comprehensive review of literature is an essential part of any scientific investigation. Apart from determining the work done in the past, assisting in delineation of insight and procedures, it forms the basis for interpretation of findings and provides a basic theoretical framework. The literature related to the present research work “Soil fertility status of paddy and sugarcane growing areas of village Butlaw and Dabhalia of Navsari district” is presented in this chapter.

2.1. Morphological characteristics of profile soil

2.1.1 Physiography

Patil and Prasad (2004) studied four representative pedons of Sal supporting soils in Dindori district of Madhya Pradesh which occurred on foot slope (8 to 15 %), flat topped hill (1 to 3 %), foot slope (5 to 10 %) and scrap slope of hills (15 to 30 %). Pedons were developed from basalt, laterised basalt, laterite capping over basalt and laterised basalt, respectively and were moderate to severely eroded and well-drained.

Chinchmalpure *et al.* (2005) studied properties from five pedons in salt affected black soils of Jambusar talukas of Bharuch

district of Gujarat State, from cotton, sorghum and pigeonpea growing area. They observed some pedons in Mahisagar and Dhadar flood plain, alluvial plain of midland and coastal low land soils, while slope of coastal low lands pedons varied from 0-1 per cent and others varied from 1-3 per cent.

Gebrekidan and Mishra (2005) characterized and classified the soils in three topo sequences of Amensis sub-catchment of Hirna watershed. Soils in the steep slopes were shallow whereas, they became deep along the topographic lows.

Maji *et al.* (2005) characterized the soils developed from basaltic parent material of Ringnabodi watershed of Nagpur district. They identified the land forms as summit crest, escarpments, isolated mounds, denuded plateau, foot slopes, upper piedmont, lower piedment and narrow valley floor. The general slope ranged between 1 and 3 per cent with exception on the fringes, which exceeded 5 to 8 per cent. Extreme erosion occurred in these soils due to presence of deep gullies and proto-gullies.

Gabhane *et al.* (2006) characterized fourteen pedons in Akola district of Vidarbha region of Maharashtra. They reported that the average slope of the watershed was modal average (1 to 3 %) and soils were moderately well-drained to well-drained, slight to severely eroded (e_1 to e_3).

Kantharaj *et al.* (2015) worked on soil site suitability for cotton, pigeonpea and sorghum growing area of upland, midland and lowland of a micro-watershed of Karnataka. Among ten pedons the slope varied from nearly level (0-3 per cent) to gently sloppy land (5-8 per cent).

Visalakshi Devi and Naidu (2016) worked on land evaluation for alternate land use planning of sugarcane growing soils of Chittor

district in Andhra Pradesh and they found that the site characteristics such as elevation, slope, erosion, drainage varied with the micro-topographic situation of the soils, indicating the important role of landforms responsible for various sites. The slope of the study area ranged from 0 to 8 per cent. The soils were moderately well drained to well drained.

2.1.2 Horizon development

Soil profile development is basically a re-arrangement of soil particles into soil horizons, each of them with specific properties. Soil formation can proceed rather fast in aggressive humid tropical climates, but is much slower in cold or dry climates. Well developed soil structure in the sub surface horizon is an indication of moderate to high degree of soil development (Sharma *et al.*, 1997).

Patel (2001) found that Fine, smectitic (calcareous), hyperthermic, Typic Haplustepts of nearly leveled landform having the horizon sequence of Ap, B₂₁, B₃₁, B_{32ca}, B_{33ca}, IIC_{ca} in micro watershed 5B2D6a of Jalalpore taluka of Navsari district.

The black soil pedons of Wardha district of Maharashtra exhibited Ap, AB, Bw, Bw₁, Bss₁, Bss₂, Bss₃; AP, Bw, BC₁, BC₂, BC₃; AP, Bw₁, Bw₂, Bw₃, Bw₄, BC; Ap, Bw, BC, C₁, C₂; Ap, Bw₁, Bw₂, Bc, 2C; Ap, Bw, Bss₁, Bss₂, Bss₃; Ap, Bw₁, Bw₂, Bw₃, Bw₄, Bw₅ and Ap, Bw₁, Bw₂, Bw₃, 2C horizon sequences (Kadao *et al.*, 2003).

Chinchmalatpure *et al.* (2005) reported Ap, Bw₁, Bw₂, Bw₃, C; Ap, A₁₂, Bss₁, Bss₂, BC; Ap, A₁₂, Bss₁, Bss₂, C; A₁, Bw₁, Bw₂, Csa and A₁, Bw₁, Bw₂, Csa horizon sequence in salt affected black soils of Jambusar taluka of Bharuch district of Gujarat.

Najar *et al.* (2009) observed better soils development in northern aspect of some apple growing soils of Kashmir due to high organic matter which retains water for longer time and releases it slowly there by enabling to pass through columns and results in well developed soils.

Niranjana *et al.* (2013) found that soils of Pulivendla region of Andhra Pradesh having horizon sequence of Ap, Bw; Ap, Bt1, Bt2, Bt3, Bt4; Ap, Bt1, Bt2, Bt3, Bt4; Ap, Bw, Bss1, Bss2; Ap, Bw1, Bw2, Bw3; and Ap, Bw, Bss1, Bss2, Bss3.

Veeresh *et al.* (2016) found that soils developed on a toposequence of schist landform in Yadgir district of Karnataka having the horizon sequence of Ap, Bt, BC, C; Ap, Bw1, Bw2, Bw3, Ck and Ap, Bss1, Bss2, Bss3, BC, C.

2.1.3 Boundary between adjacent horizons

It was observed that the black soils of Bapatla, Karlapalem region of Andhra Pradesh showed gradual to clear boundary in between the top layers, whereas, lower layers exhibited gradual smooth to diffuse smooth boundary between them (Rama Lakshmi, 1999).

In Singarayakonda, Prakasam district of Andhra Pradesh black soils had clear wavy, gradual smooth, diffused boundaries, while the sandy soils exhibited clear diffuse, gradual smooth and diffused smooth boundaries (Ramesh *et al.*, 2002).

The boundary between the adjacent horizons was clear smooth or gradual smooth in Alfisols of eastern region of Uttar Pradesh (Singh and Agarwal, 2005).

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor

district in Andhra Pradesh. They found distinctness in boundary of clear and diffuse; topography boundary of smooth and wavy.

Reddy and Naidu (2016) worked on characterization and classification of soils in semi-arid region of Chennur mandal in Kadapa district of Andhra Pradesh. They observed distinctness boundary of clear, gradual and diffuse; topography boundary of smooth and wavy.

2.1.4 Soil Depth

Maji *et al.* (2005) found that the depth of soils of Ringnabodi watershed of Nagpur district changed from 33 to 140 cm with changing topographic position.

Sitanggang *et al.* (2006) revealed that the depth of soils in watershed area of Shikohpur of Gurgaon district in Haryana varied from 35 to >150 cm due to variation in topography and slope gradient.

Dhale and Prasad (2009) studied Sweet Orange-growing- soils of Jalna district of Maharashtra and found that soils were shallow, moderately deep and deep to very deep.

Das and Shinde (2014) studied seven pedons from Sarvar village of Dangs district and reported that the depth of pedons varied from very shallow to very deep (7 to 165 cm).

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor district in Andhra Pradesh. They found the solum depth varied from deep to very deep.

2.1.5 Distribution of roots

Thangasamy *et al.* (2005) noticed that the roots in most of the horizons of Sivagiri micro-watershed of Chittoor district in Andhra

Pradesh were firm followed by coarse and medium in size and many to very few in quantity. Further, roots were abundant in surface layer and decreased with depth.

Tripathi *et al.* (2006) indicated that fine roots were abundant in surface layer of Kiar-Nagali micro-watershed in North-West Himalayas and decreased with depth.

Leelavathi *et al.* (2009) observed that the roots in different horizons of pedons of Yerpedu mandal of Chittoor district in Andhra Pradesh were fine to coarse and very few to common in quantity. Further, roots were abundant in surface layer and decreased with depth.

Das and Shinde (2014) studied seven pedons from Sarvar village of Dangs district and reported that all the pedons showed abundant amount of root (fine and coarse and few and many in quantity) in surface layer which decreased with depth.

2.2 Physical properties of soil

2.2.1 Soil Texture (Particle size distribution)

Rudramurthy *et al.* (2007) found that soil texture in Shimoga district of Karnataka irrespective of the land use systems was finer in the subsurface horizons than in the surface horizons and this might be due to the pedogenic process *viz.*, clay illuviation. The soil under mixed forest recorded finer (sandy clay) soil texture especially at surface compared to the soils under cultivated (paddy-sandy clay loam to clay loam, sugarcane and tobacco- gravelly sandy clay loam) land use systems.

Gangopadhyay *et al.* (2008) indicated that soils of South Tripura district were fine loamy in texture except Chhattaria soils which were fine loamy over coarse loamy in texture due to deposition

of alluvial materials in different fluvial cycles. The finer texture of the soils of flood plains and valley were due to the deposition of finer particles from the surrounding uplands (*tillalands*) developed on shales and siltstones due to erosion. The sand/silt ratio showed lithological discontinuities in Khilpara and Chhataria pedons indicating the formation of these soils on highly stratified alluvium.

Dhale and Prasad (2009) indicated that the sand, silt and clay content of sweet-orange growing soils of Jalna district of Maharashtra ranged from 14.4 to 46.9, 8.1 to 27.3 and 38.1 to 66 per cent.

Ashokkumar and Jagdish Prasad (2010) reported that some typical sugarcane growing soils of Maharashtra having the Sand, silt and clay content ranged from 24.2 to 62.5, 5.6 to 45.2 and 5.0 to 70.2 per cent in different horizons.

Satyavathi *et al.* (2012) studied two basaltic Vertisols series of Gujarat and reported that in Semla series per cent sand, silt and clay content were 7.3 to 23.7, 26 to 33 and 37 to 67, respectively, whereas in Sokhda series per cent sand, silt and clay content were 8.5 to 37.3, 20 to 43 and 41 to 55, respectively. These soils were interpreted as vertic paleosols based on high clay content (> 40 to 60%), most of which was smectite accompanied by intersecting slickensides and mukkara structure.

In connection with soil site suitability for cotton and other crops in Cuddalore district of Tamil Nadu, Arunkumar and Sriramachandrasekharan (2013) studied three pedons and found that sand, silt and clay percent ranged from 20.7 to 33.1 per cent, 14.8 to 18.2 per cent and 52.1 to 61.1 per cent, respectively in first pedon, while the corresponding values were from 38.4 to 45.7 per cent, 41.3 to 45.3 per cent and 13.0 to 17.8 per cent, respectively in second

pedon. Third pedon had sandy in nature, containing 90.9 to 91.7 per cent sand.

Das and Shinde (2014) for seven pedons from Sarvar village of Dangs districts reported that texture of soils (<2 mm) from different horizons of pedons varied from clay to sandy loam.

Paramasivan and Jawahar (2014) studied some black cotton soils of southern Tamil Nadu. Clay content in the surface and subsurface soils of four pedons increased with depth, ranging from 49.5 to 52.2 and 50.7 to 53.7 per cent, respectively. The gravel and sand contents were lower in soils whereas, the clay and silt contents were higher.

Kantharaj *et al.* (2015) worked on soil site suitability for cotton, pigeon pea and sorghum growing area of upland, midland and lowland of a micro-watershed of Karnataka. They found that sand, silt and clay contents in different soil series ranged from 20.5 to 82.7, 5.8 to 28.8 and 11.5 to 63.9 per cent, respectively. Higher clay content was observed in lowland followed by midland and upland soils.

Singh *et al.* (2016) worked on characterization of sodic soils and suggestion for management of Chambal command area of Madhya Pradesh and found that the soil texture of pedons varies from sandy loam, sandy clay loam, clay loam to clay.

Visalakshi Devi and Naidu (2016) worked on land evaluation for alternate land use planning of sugarcane growing soils of Chittoor district in Andhra Pradesh and they found that most of the soils were sandy loam to sandy clay loam in surface horizons and sandy to clay loam in sub-surface horizons. The sand, silt and clay content of the soils varied from 3.70 to 94.40, 2.20 to 39.60 and 1.99 to 39.11 per cent respectively.

2.2.2 Soil structure

The surface structure of Vertisols of Nasik was moderate medium sub-angular blocky which gradually changed to moderate strong angular blocky in the zone of pressure faces or coarse strong angular blocky in slickensides zone (Balapande *et al.*, 2007).

Rao *et al.* (2008) found that the Structure of soils of Ramachandrapuram mandal of Andhra Pradesh was single grained, crumb, sub-angular to angular blocky in plains, sub-angular to angular blocky in upland and sub-angular blocky on hill slope. The variation in soil structure was a reflection of physiographic position of pedons.

Gangopadhyay *et al.* (2008) found that soils of Tripura district had moderate sub-angular blocky structure in the sub-surface horizons indicating the formation of an altered B (*cambic*) horizon.

Dhale and Prasad (2009) indicated that the dominant structure of Sweet-Orange growing soils of Jalna district was moderate medium sub-angular blocky (in Inceptisols), but it was angular blocky in sub-soils (in Vertisols), because peds of sub-surface horizons had pressure faces.

Ashokkumar and Prasad (2010) reported that typical sugarcane growing soils of Maharashtra are dominantly moderate, medium and sub-angular blocky type, but angular blocky structure is a common feature in slickenside zone of Vertisols.

Arunkumar and Sriramachandrasekharan (2013) studied three soil series for soil site suitability for cotton and other crops in Cuddalore district of Tamil Nadu. They found that medium strong subangular blocky structure in surface soils, while lower horizons showed coarse strong angular blocky structure.

Das and Shinde (2014) for seven pedons from Sarvar village of Dangs district reported that structure of soils from different horizons of pedons were either weak sub-angular blocky or massive- structure less or massive moderate sub-angular blocky or coarses sub-angular blocky.

Paramasivan and Jawahar (2014) studied soils for different characters in black cotton soils of southern Tamil Nadu. They reported that the structure of the soils was mainly sub angular blocky.

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor district in Andhra Pradesh. They found the structure of the soils was single grain, crumb, sub-angular blocky and angular blocky. The blocky structures were due to the presence of higher quantities of clay fraction. The crumb structure is due to continuous addition of organic matter through vegetation.

Singh *el al.* (2016) worked on characterization of sodic soils and suggestion for management of Chambal command area of Madhya Pradesh and found that the soil structure of pedons ranges from fine to moderate, angular to sub-angular blocky.

2.2.3 Soil consistency

According to Nagassa and Gebrekidan (2003) the consistence of Alfisols and Inceptisols of Bako soils was varying from slightly hard to hard, very friable to friable and slightly sticky to slightly plastic under dry, moist and wet conditions, respectively.

Raj-Kumar *et al.* (2005) found that Gahri Bhagi Bathinda and Nihal Khera Abohar soils were moist firm, Gahri Bhagi Abohar were moist friable and moist firm in consistency, while Jodhpur Ramana soils were varied in consistency.

Thangasamy *et al.* (2005) observed that the consistence of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh was loose to very hard (dry), loose to very firm (moist) and non-sticky and non-plastic to very sticky and very plastic (wet).

Rao *et al.* (2008) showed that soils located on hill slope of Ramachandrapuram mandal in Andhra Pradesh were slightly hard to very hard (dry), friable to firm (moist) and slightly sticky and slightly plastic to sticky and plastic (wet) in consistency as a result of variation in clay content of pedons situated on different topographic positions.

Dhale and Prasad (2009) indicated that the peds of surface horizons of sweet-orange growing soils of Jalna district exhibited hard (dry) and friable/ firm (moist) consistency.

Najar *et al.*, (2009) observed that the consistence of the soils in apple growing area of Kashmir was soft to very hard (dry), firm to friable (moist).

Das and Shinde (2014) for seven pedons from Sarvar village of Dangs district reported that slightly to very hard consistency under dry condition, friable to very friable of firm under moist condition, slightly sticky to very sticky and non-plastic under wet condition. The variation in soil consistency was due to the variation in clay type and content. The higher degree of stickiness was observed in soils at upper elevation as compared to those at lower elevation under wet condition.

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor district in Andhra Pradesh. They found that the consistency of the soil varied from loose to very hard (dry), loose to very firm (moist) and non-sticky and non-plastic to very sticky and very plastic (wet).

2.2.4 Soil bulk density

Maji *et al.* (2005) found that the bulk density of shrink-swell soils of Ringnabodi watershed of Nagpur district varied from 1.33 to 1.79 Mg m⁻³. The variation in bulk density might be attributed to the moisture content and high content of expanding type of clay minerals present. They opined that increase of bulk density with soil depth might be due to over-burden pressure causing compaction in the subsurface horizons, while the surface soils were less compact probably due to high amount of organic matter and plant root concentration.

The higher bulk density in soils of Shikohpur watershed of Gurgaon district, Haryana as reported by Sitanggang *et al.* (2006) was due to their coarse texture and in some cases the presence of calcium carbonate and low organic carbon content.

Bidari *et al.* (2008) found that the black soil profiles of Dharwad, Karnataka had low bulk density (1.13 to 1.52 Mg m⁻³) which might be due to presence of high clay content in black soil, while, high bulk density (1.46 to 1.59 Mg m⁻³) in red soil pedons was due to amount of clay content and more of coarser fractions.

Rao *et al.* (2008) found that the bulk density varied from 1.45 to 1.66 Mg m⁻³ in soils of different physiographic units of Ramachandrapuram mandal of Andhra Pradesh. The bulk density of soils irrespective of landforms increased with depth, which might be due to more compaction of finer particles in deeper layers caused by overhead weight of the surface soils. Low bulk density of surface soils could be attributed to higher organic matter content.

Dhale and Prasad (2009) observed that the bulk density of sweet-orange growing soils of Jalna district varied from 1.29 to 1.96 Mg m⁻³ with general increase down the depth. However, relatively

higher bulk densities were found in surface layers of some profiles than the sub-surface horizons due to presence of gravels in higher proportion.

Leelavathi *et al.* (2009) revealed that the bulk density of different pedons of the Yerpedu mandal soils of Chittoor district varied from 1.15 to 1.61 Mg m⁻³ with an increasing trend with depth which might be due to more compaction, lower organic matter and less aggregation.

Ashokkumar and Jagdish Prasad (2010) reported that the some typical sugarcane growing soils of Maharashtra bulk density varies from 1.54 to 1.95 Mg m⁻³.

Das and Shinde (2014) for seven pedons from Sarvar village of Dangs district reported that bulk density of soils (<2mm) from different horizons of pedons varied from 1.48-1.94 Mg m⁻³ with mean value of 1.67 Mg m⁻³ and the value of which was generally higher at higher elevation or upper pediment.

Rajan *et al.* (2014) worked on assessment of some soil physical indicators in severely eroded lands of southern Karnataka and found bulk density decreased with depth in both the upland as well as midland except in lowland soils where deposits of fine particle and intensive cultivation with high organic input reduced the bulk density at the surface layers.

Reddy and Naidu (2016) worked on characterization and classification of soils in semi-arid region of Chennur mandal in Kadapa district of Andhra Pradesh. They observed that the bulk density of different pedons varied from 1.07 to 1.58 Mg m⁻³ and attributed to high content of expanding type of clay minerals. Bulk density of sub-surface horizons was higher than that of surface horizons and increased with depth.

Singh *et al.* (2016a) studied the productivity and suitability of orange growing soils of hot and semi-arid region of Rajasthan and reported that bulk density of soils varied between 1.07 to 1.74 m⁻³.

2.2.5 Porosity

Wicklund and Whiteside (1959) in the toposequence of the Caribon Catena, in New Brunswick, Canada found that there was a sharp decrease in non-capillary porosity with depth in the lower parts of the B horizons. The layers with low capillary porosity come closer to the land surface from the crest to the foot of the slope.

Savalia and Gundalia (2009) observed inverse relationship between porosity and bulk density of soil across the toposequences of southern Saurashtra of Gujarat.

Patel (2010) reported that the pore space ranged from 34.43 to 47.76 % (weighted mean of 42.55 %) in the soils of different land slopes of Meghal Irrigation Command area in southern Saurashtra of Junagadh district (Gujarat).

Rajan *et al.* (2014) worked on assessment of some soil physical indicators in severely eroded lands of southern Karnataka and found porosity of the soil in different pedons varied from 33.6 to 44.7 per cent.

2.2.6 Water holding capacity

Kadao *et al.* (2003) reported that the water retention in black soils of Wardha district of Maharashtra was more dependent on clay content in different horizons.

Nagassa and Gebrekidan, (2003) reported that water retentions at field capacity and permanent wilting point increased with depth in cultivated soil but it was not so in virgin land.

Basava Raju *et al.* (2005) reported that water holding capacity of different pedons in Chandragiri mandal of Chittoor district, Andhra Pradesh varied from 15.43 to 52.34 per cent in plains, 22.00 to 38.50 per cent in upland and 32.73 to 38.50 per cent on hill slope.

The water holding capacity in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh ranged from 13.05 to 58.99 per cent. These differences were due to the variation in the depth, clay, silt and organic carbon content in the soils (Thangasamy *et al.*, 2005).

Balpande *et al.* (2007) found that the water retention in different horizons of the soils of Nasik district varied from 19.56 to 50.22 at 33 KPa and 9.81 to 30.94 at 1500 KPa.

Thangasamy *et al.* (2005) reported that the water holding capacity of Alfisols of Sivagiri micro-watershed was varying between 25.50 and 46.64 per cent in different horizons.

Reddy and Naidu (2016) worked on characterization and classification of soils in semi-arid region of Chennur mandal in Kadapa district of Andhra Pradesh. They observed that water holding capacity of different pedons varied from 25.59 to 50.01 per cent. These variations were due to the difference in depth, clay, silt and organic carbon content of the soils.

Singh *et al.* (2016a) studied the productivity and suitability of orange growing soils of hot and semi-arid region of Rajasthan and reported that with respect to parent materials, soil developed from basalt had higher water retention than the soils developed from sandstone and shale at 0.03 and 1.5 Mpa tensions. In general, moisture retention increased with down the depth of profile.

2.2.7 Soil colour

Maji *et al.* (2005) observed that soils of higher elevation in Ringnabodi watershed of Nagpur district had dark brown (7.5YR hue) and those on lower elevation had dark brown to very dark gray and very dark greyish brown (10YR hue) colour. They stated that the presence of ferromagnesian minerals was the cause of dark colour.

Tripathi *et al.* (2006) in North-West Himalayas for the typical pedons of Kiar-Nagali micro-watershed revealed that the colour of surface horizons varied from dark brown (10YR 3/3) to yellowish brown (10YR 5/4), while the sub-surface horizons were brown (10YR 4/3) to dark yellowish brown (10YR 4/4). The dark matrix colour was due to the presence of high organic matter content in the soils.

Dhale and Prasad (2009) reported that the Munsel colour notation of Sweet Orange-growing soils of Jalna district was 10YR/7.5YR/ 5 YR hue with value 3 to 4 and chroma 1 to 4.

Ashokkumar and Prasad (2010) reported that some typical sugarcane growing soils of Maharashtra are having the Munsell colour notation of 10YR/7.5YR hue with a value of 3 to 4 and chroma of 1 to 4.

Das and shinde (2014) for seven pedons of Sarvar village of Dang districts reported that colour of different horizons of pedons varied widely. However, with increase in physiographic position, soil colour generally changed from yellow or yellowish to red or reddish.

Singh *et al.* (2016) worked on the characterization of sodic soils of Chambal command area of Madhya Pradesh and found that soils vary in colour from yellowish brown (10 YR 5/4 D), dark brown (10 YR 4/3 D) to dark grey brown (10 YR 4/2 D).

Singh *et al.* (2016a) studied the productivity and suitability of orange growing soils of hot and semi-arid region of Rajasthan and

reported that the colour of soils ranged between pale brown (10 YR 6/3) to black (10 YR 2/1).

2.2.8 Water stable aggregates (WSA)

Bandyopadhyay *et al.* (2010) reported that aggregate ratio (AR) ranged from 1.72 to 3.10 in cultivated surface soils under different organic and inorganic inputs.

Choudhury *et al.* (2010) studied *Inceptisol* profiles from humid tropical region of West Bengal for soil aggregation. Under upland cultivated soil, WSA (%) retained 4.00, 4.24, 11.87, 13.35, 8.09 and 58.45% respectively on >2.0, 1.0-2.0, 0.5-1.0, 0.25-0.5, 0.1-0.25 and <0.1 mm size sieves and also having MWD of 0.94 mm.

Jiang *et al.* (2011) studied the aggregate size distribution and MWD from subtropical rice soil under variable tillage and they reported that the MWD was significantly affected by tillage treatments, showing a higher value (1.211 mm) under no-till (NT), than that (0.787 mm) under conventional tillage (CT).

Jovanov *et al.* (2012) studied seven Vertisols profiles for aggregate composition and water stability of structural aggregates at Republic of Macedonia. In upper two horizon-soils of profile, WSA-distribution of < 0.25 mm size ranged from 12.5-18.7, 3.5-13.5, 17.2-18.3, 23.0-24.0, 12.3-13.0, 20.7-19.1 and 23.9-30.3 per cent, respectively and 84.14 to 89.94 per cent, respectively and for > 0.25 mm sieve size-WSA were 81.3-87.5, 86.5-96.5, 81.8-82.8, 76.0-77.0, 87.0-82.0, 79.3-80.9 and 69.7-76.1 per cent, respectively.

Kadam *et al.* (2012) studied physical characteristics of seven profile (Vertisols) soils at different locations under Majalgaon canal command (Jayakwadi project stage-III). They found that the per cent aggregates greater than 0.25 mm diameter varied from 33 to 81 in

deep Vertisols, 16 to 60 in medium deep Vertisols and 21 to 24 in shallow black soils.

Rajan *et al.* (2014) worked on assessment of some soil physical indicators in severely eroded lands of southern Karnataka and found average per cent of microaggregates in the pedon varied from 20.1 percent to 24.9 percent. The highest amount of microaggregate was observed under natural forest soil and the lowest in severely eroded lands.

2.3 Chemical properties of soil

2.3.1 Soil reaction (pH)

The pH values of surface and subsurface sandy loamy soils of subtropical region of Jammu and Kashmir were 7.4 to 8.6 and 7.0 to 8.3, respectively (Sharma *et al.*, 2009).

Jatav (2010) studied on fertility evaluation in *Inceptisols* of Baloda block of Janjgir district of Chhatisgarh and reported the pH in the range from 4.7 to 7.50 with the mean value 5.89.

Jayaprakash *et al.* (2012) reported that areca nut growing soils of southern Karnataka region were moderately acid (5.6) to slightly alkaline (8.5) in surface soil.

Khan and Kamalakar (2012) found that soils of agro-biodiversity park of Acharya NG Ranga Agricultural University of Haderabad in Andhra Pradesh were neutral to moderately alkaline (6.5 to 8.04) in reaction.

Patel *et al.* (2012) observed soil site suitability evaluation for soybean in Meghal irrigation command area of southern Saurashtra region of Gujarat, the soils study area were moderately alkaline in reaction and highly calcareous in nature.

Singh *et al.* (2014) studied the soils of Chambal region of Madhya Pradesh and found the alluvial and medium black soils were neutral to alkaline, whereas ravenous land was more or less neutral.

Nadaf *et al.* (2015) conducted field survey to study the micronutrient constraints in sugarcane growing Vertisols of northern Transition Zone of Karnataka reported that the majority of the area was slightly saline to alkaline in nature and remaining less amount of area was found acidic with a soil pH range of 6.60 - 9.69.

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor district in Andhra Pradesh were near neutral (6.90) to strongly alkaline (9.61).

Reddy and Naidu (2016) found that soils in semi-arid region of Chennur mandal in Kadapa district of Andhra Pradesh were slightly alkaline to strongly alkaline (pH 7.4 to 8.5) in reaction.

Visalakshi Devi and Naidu (2016) worked on land evaluation for alternate land use planning of sugarcane growing soils of Chittoor district in Andhra Pradesh and they found that the soils were near neutral to strongly alkaline in reaction (pH 6.90 to 9.61).

2.3.2 Electrical conductivity

Leelavathi *et al.* (2009) studied seven typical pedons of Yerpedu mandal in Chittoor district of Andhra Pradesh. They found that all the pedons showed low to medium EC (0.03 to 1.24 dS m⁻¹). The reason for low EC was free drainage conditions which favoured the removal of released bases by percolating and drainage water.

Pujar *et al.* (2010) studied surface soils (0-20cm) of sugarcane growing area of five talukas from Bijapur district and reported that

the electrical conductivity (EC) of the soil varying from 0.08 to 2.38 mmhos cm^{-1} .

Kumar and Babel (2011) studied soils of Jhunjhunu tehsil in Rajasthan and reported that the soils were non saline in nature, where $\text{EC}_{(1:2)}$ varied from 0.20 to 2.14 dS m^{-1} with mean of 1.05 dS m^{-1} .

Patel *et al.*, (2012) studied soil site suitability evaluation for soybean in Meghal irrigation command area of southern Saurashtra region of Gujarat, the soils on higher altitude have low EC ranging from 0.26 to 0.81 dS m^{-1} than the soils on lower altitude.

Choudhary *et al.* (2012) studied one hundred surface soil samples from two tehsils of Agra district of Uttar Pradesh. They reported that EC of soils varied between 0.10 and 0.49 dS m^{-1} . The EC variation within the soils of Sadar and Etmadpur tehsil were from 0.12-0.41 and 0.10-0.49 dS m^{-1} , respectively.

Athokpam *et al.* (2013) studied soil macro and micro nutrients of Senapati district (rice crop with alluvium, lateritic black regur and red ferruginous soil type) of Manipur and they reported that EC varied from 0.02 to 0.22 dS m^{-1} with mean of 0.07 dS m^{-1} . They opined that wide variation of soil EC might be due to the different concentration of basic cations.

Vijayakumar and Haroon (2013) studied physicochemical and nutrient status of sugarcane growing soils of three soil series of Theni district of Tamil Nadu. They reported that electrical conductivity (EC) from 0.03 to 1.64 dS m^{-1} . The soils of Somayyanur, Palaviduthi and Irugur series recorded average soil EC of 0.24, 0.26 and 0.28 dS m^{-1} in chronological order.

Das and Shinde (2014) studied seven pedons from Sarvar village of Dang districts and reported that EC varied from 0.026-0.057 dS m⁻¹ with mean value of 0.040 dS m⁻¹ in pedons.

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor district in Andhra Pradesh were non-saline. The EC of soil water extract in sugarcane growing soils ranged from 0.01 to 0.41 dS m⁻¹. The low EC in the soils was due to free drainage conditions which favoured the removal of released bases by percolating and drainage water.

Singh *et al.* (2016a) studied the productivity and suitability of orange growing soils of hot and semi-arid region of Rajasthan and reported that electrical conductivity of soils ranged from 0.10 to 0.30 and 0.08 to 0.91 dS m⁻¹ in Vindhyan scarplands and Malwa plateau, respectively.

2.3.3 Organic carbon

Leelavathi *et al.* (2009) found that the organic carbon of Yerpedu mandal soils of Chittoor district was low (0.05 to 0.44 per cent) which might be due to the prevalence of tropical condition, where degradation of organic matter occurred at a faster rate coupled with low vegetation cover. It decreased with depth due to the addition of plant residues and farmyard manure to surface horizons.

Organic carbon content of Punjab soils varied between 0.40 to 0.75 per cent. It may be the result of heterogeneous landscape and rapid oxidation of organic matter due to high temperature and aerobic conditions throughout the year in this region (Bali *et al.*, 2010).

Pujar *et al.* (2010) characterized surface soils (0-20cm) of sugarcane growing area from five talukas of Bijapur district. They revealed that irrespective of talukas, organic carbon content of soils was in the range of 0.29 to 1.24 per cent. In most of the samples, organic carbon content was higher which could be attributed to good vegetable growth and the consequent addition of organic matter to the soil in that area.

Jayaprakash *et al.* (2012) reported that areca nut growing soils of southern Karnataka region had organic carbon ranged from 3.3 to 19.0 mg kg⁻¹.

Khan and Kamalakar (2012) found that soils of agro-biodiversity park of Acharya NG Ranga Agricultural University of Hyderabad in Andhra Pradesh had organic carbon content ranged from 0.14 to 0.96 per cent. The surface horizons of all the profiles were higher in organic carbon than sub-surface horizons. A general trend of decreasing organic carbon with depth was observed in all the profiles.

Athokpam *et al.* (2013) studied soil macro and micro nutrients of Senapati district (rice crop on alluvium, lateritic black regur and red ferruginous soil) of Manipur and they reported that SOC ranged from 6.0 to 25.2 mg kg⁻¹ with average of 14.74 mg kg⁻¹. The high organic carbon in the soil was due the luxuriant grasses growth along with the seasonal decomposition of vegetative parts and roots.

Behera and Shukla (2013) studied depth-wise distribution of micronutrients in acid soils of India and their relationship with some soil properties. They found that the mean of soil organic carbon decreased with increase in soil depth across the site.

Pal and Selassie (2013) studied physicochemical properties of soils from Tendaho of Assaiyita and reported that the average carbon

contents in most of the sugarcane grown soils ranged from 2.0 to 7.7 mg kg⁻¹ which is low to medium.

Vijayakumar and Haroon (2013) studied sugarcane growing soils from three soil series of Theni district of Tamil Nadu. They reported that the highest mean soil organic carbon (5.6 mg kg⁻¹) was associated with Palaviduthi series, while the lowest was observed in the Somayyanur and Irugur soil series with mean of 5.3 mg kg⁻¹. In case of low organic carbon status (< 0.5 per cent), 50, 47 and 46 percent soils respectively from Irugur (Total 95 samples), Palaviduthi (Total 159 samples) and Somayyanur soil series (Total 146 samples) belonged to low category.

Das and shinde (2014) studied seven pedons from Sarvar village of Dang district reported that organic carbon of soils from different horizons of pedons varied from very low to high (0.97 to 13.53 mg kg⁻¹) with mean value of 3.78 mg kg⁻¹ and showing decreasing trend with depth of soil.

2.3.4 CaCO₃ content

Maji *et al.* (2005) observed high amount of calcium carbonate ranging from 50 to 248 mg kg⁻¹ in soils developed from basaltic parent material. The calcium carbonate content increased with depth and this may be due to leaching of bicarbonates during the rainy season and their subsequent precipitations as carbonate in lower layers.

In aridisols of Punjab the amount of calcium carbonate ranged from 19 to 174 g kg⁻¹ in different horizons but lack a definite trend in distribution. This irregular distribution is due to variable nature of geological material that contributed to the aeolian or alluvial soils or due to rapid leaching from these sandy soils (Raj-kumar *et al.*, 2005).

Gill *et al.* (2012) found calcium carbonate content ranged from 0.24 to 1.43 per cent in different soils of Phalasia block of Udaipur district, Rajasthan and increased with depth.

Kaleeswari (2012) studied the soils of northern Villupuram district of Tamil Nadu and found the free calcium carbonate content ranges from 0.50 per cent to 9.50 per cent with a average value of 2.23 per cent.

Singh *et al.* (2014) studied the alluvial and medium black soils and ravinous land of Chambal region of Madhya Pradesh and found that the soils were low in calcium carbonate content.

Gandhi and Savalia (2016) studied the calcareous basaltic soils of Girnar toposequence in southern Saurashtra region of Gujarat and found soils contained high calcium carbonate. The calcium carbonate ranged from 2.30 to 78.78 per cent with a mean of 27.67 per cent, indicating the soils were highly calcareous in nature.

Singh *et al.* (2016a) studied the productivity and suitability of orange growing soils of hot and semi-arid region of Rajasthan and reported that in Vindhyan scarplands calcium carbonate varied between 26.3 and 223.8 g kg⁻¹, however in Malwa plateau it was ranged from 40.0 to 224.7 g kg⁻¹. The distribution of calcium carbonate showed an increasing pattern with an increase in the depth of pedons. This was due to downward movement of calcium ions and precipitated in sub-surface layers at higher pH level.

2.3.5 Cation exchange capacity

Rao *et al.* (2008) found that the CEC in soils of Ramachandrapuram mandal in Andhra Pradesh ranged from 6.7 to 27.6 cmol(p⁺)kg⁻¹, which corresponded to clay content in the horizons.

Talukdar *et al.* (2009) determined physicochemical properties of soils from Golaghat district in Assam (in two agro-ecosystems) and reported that CEC varied from 5.8 to 7.5 and 6.4 to 7.9 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$ for rice and sugarcane soils, respectively.

Rashmi *et al.* (2009) studied paddy growing soils of upper Krishna project in Karnataka and found that exchangeable Ca^{++} of auger samples varied between 10.01 and 23.90 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$. Similarly, magnitude of exchangeable Mg^{++} was noted between 3.99 and 9.10 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$.

Leelavathi *et al.* (2009) reported that the CEC values in Yerpedu mandal of Chittoor district varied from low to medium which corresponded to clay content in the horizons, low organic carbon content and also type of clay mineral present in these soils.

Ashokkumar and Prasad (2010) reported that the some typical sugarcane growing soils of Maharashtra have CEC varied from 21.6 to 61.7 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$.

Jayaprakash *et al.* (2012) reported that areca nut growing soils of Southern Karnataka region had cation exchange capacity ranged from 9.0 to 29.0 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$.

Patel *et al.* (2012) observed soil site suitability evaluation for soybean in Meghal irrigation command area of southern Saurashtra region of Gujarat, and reported that the soils on higher altitude have CEC ranging from 26.55 to 36.54 $\text{cmol}(\text{P}^+)\text{kg}^{-1}$ than the soils on lower altitude.

Pal and Selassie (2013) studied physicochemical soil properties of Tendaho irrigation project area and reported in most of the sugarcane grown soils of study area had high CEC ranging from 33.5 to 61.3 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$.

Visalakshi Devi *et al.* (2015) reported that sugarcane growing soils of southern agro-climatic zone in eastern mandals of Chittoor district in Andhra Pradesh and found the cation exchange capacity in surface and sub-soils ranged from 1.05 to 33.34 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$, which corresponds to clay content in the horizons, organic carbon content and also type of clay mineral present in these soils.

Singh *et al.* (2016) worked on characterization of sodic soils and suggestion for management of Chambal command area of Madhya Pradesh and found that the cation exchange capacity ranged from 13.56 to 34.45 $\text{cmol}(\text{p}^+)\text{kg}^{-1}$. In general, the cation exchange capacity decreased with increasing soil depth.

2.3.6 Exchangeable sodium percentage (ESP)

Balpande *et al.* (2007) characterized the grape-growing soils in Nasik district, Maharashtra. They found that the ESP in soils increased with depth of soil from 1.0 to 10.7.

Savalia and Gundalia (2009) found that the ESP values of selected pedons of Southern Saurashtra region of Gujarat varied from 6.95 to 11.79. The lower values of ESP in hill slope as well as upper piedmont pedons might be due to the washing down of salts by rain or irrigation water, while the higher in piedmont plain might be due to its mobility and position of profile in transect, poor drainage, shallow ground water and high Na-salts.

Gandhi and Savalia (2014) worked on soil-site suitability for mustard in calcareous soils of Girnar toposequence in southern Saurashtra region of Gujarat and found exchangeable sodium percentage of soils increased from hill slope to coastal depression. The higher value of exchangeable sodium percentage at lower elevated areas might be due to its mobility and position of profile in

transect, poor drainage, shallow underground water and high sodium salts.

Singh *et al.* (2016) worked on characterization of sodic soils and suggestion for management of Chambal command area of Madhya Pradesh and found that the exchangeable sodium percentage varied from 17.81 to 37.24 in different horizons.

Singh *et al.* (2016a) studied the productivity and suitability of orange growing soils of hot and semi-arid region of Rajasthan and reported that the exchangeable sodium percentage increased with depth.

2.4 Nutrient status of soil

2.4.1 Available N, P and K

Rao *et al.* (2008), in typical pedons representing major landforms of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh, observed that the soils were low in available nitrogen, low to medium in available phosphorus, and medium to high in available potassium and varied from 54 to 102 kg ha⁻¹, 9.29 to 23.96 kg ha⁻¹ and 135 to 320 kg ha⁻¹, respectively. The respective nutrient index values were 1.0, 1.96 and 2.37.

Sharma *et al.* (2008) studied spatial distribution of nitrogen, phosphorus and potassium at Amritsar district of Punjab. The content of available nitrogen varied from 63 to 170 kg ha⁻¹, available phosphorus from 9.4 to 84.9 kg ha⁻¹, available potassium from 84 to 700 kg ha⁻¹.

Talukdar *et al.* (2009) reported that irrespective of land use, the available nitrogen, phosphorus and potassium content of the soils of Golaghat district of Assam (in two agro-ecosystems) varied from 205 to 479, 9.50 to 28.5 and 60 to 347 kg ha⁻¹, respectively. The rice

ecosystem showed the highest values of available N, P_2O_5 and K_2O as compared to the sugarcane one. The reason might be the high content of organic carbon which on mineralization released higher amounts of NPK as compared to those in sugarcane system.

The available nitrogen, phosphorus and potassium ranged from 47.0 to 228.9, 0.6 to 28.6 and 80.3 to 760.3 kg ha⁻¹, respectively in some typical sugarcane growing soils of Maharashtra (Ashokkumar and Prasad, 2010).

Dar *et al.* (2012) in pear orchard soils of Kashmir reported that the available nitrogen in surface (0-25cm) and sub-surface (25-100cm) soils of high altitude were 401.5 to 273.6 kg ha⁻¹, available phosphorus were 36.8 and 24.4 kg ha⁻¹ and available potassium were 416.9 and 326.9 kg ha⁻¹ respectively, while the corresponding values for mid altitude were 345.7 and 221.1, 36.0 and 24.1 and 386.5 and 276.8 kg ha⁻¹. For low altitude the values were 312.4 and 180.6, 29.8 and 21.5 and 401.6 and 224.3 kg ha⁻¹ respectively.

Athokpam *et al.* (2013) studied soil macro and micronutrients of Senapati district (rice crop on alluvium, lateritic black regur and red ferruginous soil) of Manipur and they reported that available N varied from 290.20 to 893.17 kg ha⁻¹ with mean 382.04 kg ha⁻¹, P_2O_5 varied from 24.62 to 64.37 kg ha⁻¹ with mean 38.31 kg ha⁻¹ and available K_2O varied from 55.60 to 359.11 kg ha⁻¹ with mean value of 208.86 kg ha⁻¹.

Vijayakumar and Haroon (2013) studied sugarcane growing soils from three different soil series of Theni district of Tamil Nadu. They observed that soil available N varied from 69 to 449 kg ha⁻¹ in three series with mean of 209 kg ha⁻¹ in Palaviduthi series, 208 kg ha⁻¹ in Somayyanur and 201 kg ha⁻¹ in Irugur soil series. About 95% soils recorded low nitrogen status and rest was of medium status. They

observed extreme variation in soil available phosphorus exhibiting between 9 and 183 kg ha⁻¹ where about 80 to 96 percent soils belonged to high available phosphorus status (> 22 kg ha⁻¹). The mean phosphorus status of Palaviduthi, Somayyanur and Irugur soil series were 55.83, 62.63 and 48.17 kg ha⁻¹ respectively. The available potassium content was in the range of 83 to 2010 kg ha⁻¹ with the highest mean value of 539 kg ha⁻¹ in Palaviduthi series. About 79 per cent, 70 per cent and 67 per cent of soils respectively from Palaviduthi, Somayyanur and Irugur soil series, recorded high status of available potassium (> 280 kg ha⁻¹).

Singh *et al.* (2014) studied soil fertility status of surface soils and correlation of available macro and micronutrients in Chambal region of Madhya Pradesh. The ranges of available N, P and K in were 126 to 361, 7 to 29.5 and 128 to 391 Kg ha⁻¹ respectively in alluvial soil; 178 to 408, 7.9 to 28.8 and 122 to 386 Kg ha⁻¹ in medium black soil and 125 to 301, 6.2 to 25.3 and 252 to 406 Kg ha⁻¹ in ravenous land, respectively. Of alluvial soil samples, 97 per cent were low and 3 per cent medium in N; 14 per cent low, 68 per cent medium and 18 per cent high in P; 1 per cent low, 35 per cent medium and 64 per cent high in K. Of medium black soil samples, 90 per cent were low and 10 per cent medium in N; 21 per cent low, 69 per cent medium and 10% high in P; 4 per cent low, 37 per cent medium and 59 per cent high in K. Of ravenous land soil samples, 95 per cent were low and 5 per cent medium in N; 68 per cent low and 32 per cent medium in P; 19 per cent medium and 81 per cent high in K.

Hadole *et al.* (2015) studied the nutrient status of soils of Katepurna and Kurankhed blocks of central demonstration farm of Wani-Rambhapur. They observed that soils of Katepurna block contain 132.82 to 288.51 kg ha⁻¹ available nitrogen, 5.91 to 16.12 kg

ha⁻¹ available phosphorus and 235.2 to 397.3 kg ha⁻¹ available potassium. Kurankhed block contain 125.44 to 288.51 kg ha⁻¹ available nitrogen, 6.45 to 18.81 kg ha⁻¹ available Phosphorous and 235.2 to 398.2 kg ha⁻¹ available potassium. The nutrient index value calculated for soils of Katepurna and Kurankhed block shows that these soils have low NIV for available nitrogen and phosphorus, high NIV for available potassium.

2.4.2 Available S

Sharma *et al.* (2008) studied three major landform-units viz., alluvial plain, flood plain and sand bars in Amritsar district of Punjab and reported that the available S content in the soil varied from 24.6 to 60.0 kg ha⁻¹ with an average of 37.6 kg ha⁻¹. The soils of the district were adequate in S based on 22.4 kg ha⁻¹ as critical limit for available S. However, 47, 45 and 8 percent of the samples were found to be medium, high and very high respectively in available S.

Singh *et al.* (2009) studied five hundred surface soil samples from Udham Singh Nagar district, Uttarakhand, and analyzed to assess the status of available S. The available S varied from 4.6 to 118.4 mg kg⁻¹. The soil samples testing low, medium and high in available S were 22, 31 and 47 per cent, respectively.

Patra *et al.* (2012) reported that the status of available sulphur in surface and sub-surface soils of red and lateritic soils of West Bengal ranged from 0.5 to 219.5 mg kg⁻¹ with an average of 29.5 mg kg⁻¹ in surface soil and in sub surface soil it ranged from 0.5 to 68.4 mg kg⁻¹ with an average of 18.7 mg kg⁻¹.

Chouhan *et al.* (2012) assessed sulphur status in medium black soils of Dewas district, Madhya Pradesh and reported that available S content in soils varied from 0.9 to 50.2 mg kg⁻¹ with a mean value 13.7 mg kg⁻¹. Based on 10 mg kg⁻¹ as the threshold value, about 38.6

per cent soil samples were found to be deficient. These soils were medium in sulphur status as per soil nutrient index.

Kaleeswari (2012) studied surface soil samples from 1791 locations for available sulphur in northern Villupuram district, Tamil Nadu using GPS. She reported that the available sulphur content varied from 1.25 to 198.75 mg kg⁻¹ with a mean value of 48.64 mg kg⁻¹. The highest available sulphur (66.97 mg kg⁻¹) was recorded in the Melmalayanur block.

Bhaskaran *et al.* (2012) surveyed eight sugarcane growing districts of Tamil Nadu and reported that the sulphur content of soils (up to 30 cm) varied widely from 2.45 to 96.07 ppm with an average of 25.37 ppm. About 17 per cent of the soils were found to be deficit (low) in available S content of (<10.0 ppm), 35 percent were in medium category (10 to 20 ppm) and 48 percent were in high (> 20 ppm) category.

Vijayakumar and Haroon (2013) reported that the average available sulphur content varied from 1.02 to 98.3 ppm in sugarcane growing soils of three different soil series of Theni district of Tamilnadu. 45, 26 and 24 per cent of soils from Somayyanur, Palaviduthi and Irugur soil series, respectively registered low (10 ppm as critical limit) available sulphur, while 50 percent of soils were found to be adequate in sulphur availability.

Rajput *et al.* (2015) studied the status of available sulphur in mustard growing areas of northern Madhya Pradesh and found that available sulphur in soils ranged between 4.36 to 19.58 mg kg⁻¹ with the mean value of 11.68 mg kg⁻¹.

2.4.3 DTPA extractable Fe, Mn, Cu and Zn

The soils of Ramahcandrapuram Mandal in Chittoor district of Andhra Pradesh were deficient in DTPA extractable zinc and iron, while these were sufficient in DTPA extractable copper and manganese (Rao *et al.*, 2008).

Talukdar *et al.* (2009) determined soil properties of sugarcane land use systems of Golaghat district in Assam and reported that the DTPA extractable Fe varied from 42.50 to 213.46 mg kg⁻¹ and were sufficient in Fe. The soils were found to be well supplied (86 per cent were sufficient) with DTPA extractable Zn where, 6 per cent samples were deficient and 8 per cent were marginal. DTPA extractable Mn content of the soils varied widely and was higher under rice land use system than under the sugarcane land use. Based on critical limit of Lindsay and Norvell (1978), all the soils was sufficient in DTPA extractable Mn. DTPA extractable Cu ranged from 0.35 to 6.05 mg kg⁻¹ with a mean value of 3.83 mg kg⁻¹. Based on critical limit, all the soils were sufficient in DTPA extractable Cu.

Nagendran and Angayarkanni (2010) studied sixteen pedons for vertical distribution of DTPA extractable iron, manganese, zinc and copper representing various physiographic positions of Cumbum valley of Tamil Nadu. They found that the content of micronutrients increased with the increase in organic carbon and decreased with increase in pH and free CaCO₃. In general, all these micronutrients decreased with increase in depth but they had no definite correlation with topography. As per the critical limit suggested for Tamil Nadu soils, Iron and Manganese were found to be sufficient in most soils, except calcareous and recent alluvial soils. Zinc and copper were deficient uniformly in all soils. Site-specific residual copper accumulation was also found.

Pati and Mukhopadhyay (2011) studied the distribution of cationic micronutrients in some acid soils of West Bengal and observed average content of the DTPA extractable Fe varied from 2.38 to 60.5 mg kg⁻¹. The DTPA extractable Mn content ranged from 0.40 to 6.14 mg kg⁻¹. DTPA extractable Cu content varied from 0.17 to 1.96 mg kg⁻¹. DTPA extractable Zn content varied from 0.28 to 0.91 mg kg⁻¹. A gradual decrease in the content of extractable micronutrients with the soil depths was found.

Chouhan *et al.* (2012) assessed micronutrient status in medium black soils of Dewas district, Madhya Pradesh and reported that the DTPA extractable Fe in soils varied from 4.50 to 22.5 mg kg⁻¹ with mean value of 6.80 mg kg⁻¹. Considering soil nutrient index, these soils were medium in Fe. DTPA extractable Mn in soils varied from 1.70 to 25.70 mg kg⁻¹ with mean value of 5.4 mg kg⁻¹. Considering soil nutrient index, these soils were high in Mn. DTPA extractable Zn varied from 0.04⁻¹ to 4.9 mg kg⁻¹ with a mean value of 0.49 mg kg⁻¹. Considering soil nutrient index, these soils were low in Zn. DTPA extractable Cu in soils varied from 0.24 to 5.90 mg kg⁻¹ with mean value of 1.80 mg kg⁻¹. Considering soil nutrient index, these soils were medium in Cu.

Verma *et al.* (2012) studied soils of Baghaipur, Shekhupur, Makhanpur, Rahtauli, Akbarpur, Ayana, Paigamberpur, Dhakra and Bijhalpur representing four major landforms (old alluvial plain, recent alluvial plain, ravinous land and active flood plain) in Badhpura block of Etawah district, Uttar Pradesh. They reported that DTPA extractable Fe in surface soil of above pedons were 13.55, 3.96, 11.02, 3.81, 4.81, 2.06, 2.69, 3.94 and 3.92 mg ha⁻¹, respectively. Overall, these soils were low in Fe. DTPA extractable Mn in surface soils of above profiles were 11.30, 14.25, 6.49, 18.65, 1.28, 7.14,

8.94, 11.18 and 3.43 mg ha⁻¹ respectively. Overall, these soils were sufficient in Mn. DTPA extractable Zn in surface soil were 0.50, 0.58, 0.30, 0.52, 0.51, 0.20, 0.71, 0.39 and 0.46 mg ha⁻¹ respectively. Overall, these soils were low in Zn. Similarly, DTPA extractable Cu in surface soils were 0.80, 0.66, 1.35, 1.29, 0.78, 0.51, 0.59, 0.77 and 0.16 mg ha⁻¹ respectively. Overall, these soils were low in Cu.

Vijayakumar and Haroon (2013) observed that the available iron content in sugarcane growing soils from three different soil series of Theni district of Tamilnadu varied from 1.44 to 186 mg kg⁻¹. Considering 3.7 mg kg⁻¹ as critical limit, *Irugur*, *Somayyanur* and *Palaviduthi* soil series recorded 16, 13 and 6 per cent iron deficiency, respectively. Available zinc content ranged from 0.12 to 12.78 mg kg⁻¹. About 60 per cent of soils from *Irugur*, 53 per cent of *Somayyanur* and 46 per cent of soils from *Palaviduthi* soil series, registered deficiency in available zinc. Available manganese content of soil samples ranged from 0.98 to 45.10 mg kg⁻¹. All the soil samples from these series recorded sufficiency in available Mn status. Available copper content of soil samples from all the series ranged from 0.52 to 11.13 mg kg⁻¹. Almost all the soil samples recorded sufficient status of available copper.

Singh *et al.* (2014) studied soil studied the soil fertility status of micronutrients in Chambal region of Madhya Pradesh and found 64.5, 11.7 and 14.3 per cent soils found deficient in Zn, Fe and Mn, respectively in alluvial soils; 76.3, 33.3 and 8.8 per cent samples were deficient in Zn, Fe and Mn, respectively in medium black soils and 18.4 per cent soils were deficient in Zn in ravenous land.

Nadaf *et al.* (2015) conducted field survey to study the micronutrient constraints in sugarcane growing vertisols of northern transition zone of Karnataka and reported that, maximum area under

Fe deficiency followed by zinc, boron and sufficient in the available status of manganese and copper.

Singh *et al.* (2016) worked on characterization of sodic soils and suggestion for management of Chambal command area of Madhya Pradesh and found that the ranges of Zn, Fe, Cu and Mn in mg kg⁻¹ in upper horizons 0.26 to 0.62, 3.04 to 5.65, 0.28 to 0.45 and 1.32 to 2.21 and in lower horizons from 0.32 to 0.51, 2.84 to 3.79, 0.2 to 0.35 and 1.65 to 2.69, respectively.

2.5 Correlations among soil properties

Talukdar *et al.* (2009) for sugarcane land use systems of Golaghat district in Assam reported that the available Fe was positively and significantly correlated with organic carbon content and CEC of soils which might be due to formation of organic chelating agents into soluble metallic complexes. It showed significant and negative correlation with pH, maintained positive correlation with available Mn and Cu and negative relationship with Zn under. Available Zn showed positive correlation with organic carbon, CEC and available N. Available Cu and Mn and significant negative relationship with pH. Mn showed significantly positive correlation with organic carbon and non-significant positive correlation with CEC of soils, available Fe and Zn. Available Cu had positive correlation with organic carbon, CEC, available nitrogen, phosphorus and potassium, available Fe and Zn.

In case of Vertisol from Jabalpur, Thakur *et al.* (2011) reported that SOC content exhibited significant positive correlation with available Fe (0.62**), Mn (0.65**) and Cu (0.69**) contents of the surface soil (0-20 cm). In the case of sub-surface layer (20-40 cm) they reported that soil pH had significant negative association with

micronutrient cations *i.e.* Zn ($r=-0.65^{**}$), Fe ($r=-0.65^{**}$), Mn ($r=-0.46^{*}$) and Cu ($r=-0.51^{*}$).

Chouhan *et al.* (2012) studied the status of sulphur and micronutrient in medium black soils of Dewas district, Madhya Pradesh and they found from simple correlation study that organic carbon had positive relationship with DTPA extractable Zn ($r = 0.353^{**}$). DTPA extractable Cu had negative correlation with pH ($r = -0.371^{**}$). DTPA extractable Mn had negative correlation with pH ($r = -0.683^{**}$) and had positive relationship with organic carbon ($r=0.237^{***}$). DTPA extractable Fe had negative correlation with pH ($r = -0.683^{**}$). Available sulphur had non-significant positive relationship with organic carbon ($r = 0.256$).

In sugarcane growing soils from three different soil series of Theni district Vijayakumar and Haroon (2013) observed that soil available nitrogen had significant and positive correlation with organic carbon content ($r = 0.4826^{**}$, 0.3852^{**} and 0.4247^{**}) in Palaviduthi, Somayyanur and Irugur soil series, respectively. Available potassium of Somayyanur soil series had a significant positive correlation with organic carbon ($r = 0.4254^{**}$) and available sulphur ($r = 0.4514^{**}$). However, the soils of Palaviduthi series had significant positive correlation with available nitrogen ($r = 0.3321^{*}$). Available sulphur only in soils of Somayyanur series had a significant positive correlation with organic carbon (0.3200^{*}), while the soils of Palaviduthi series had positive correlation with electrical conductivity ($r = 0.6042^{**}$). Significant and negative correlation of soil pH with available iron ($r = -0.3565^{**}$, -0.4986^{**} and -0.2996^{*}) were found in all the three series of Palaviduthi, Somayyanur and Irugur. Available Mn had significant and negative correlation with soil pH ($r = -0.6552^{**}$) in Somayyanur soil series. The available zinc showed

positive correlation with organic carbon ($r = 0.2873^*$) and significant negative correlation with pH ($r = -0.3489^*$). The available Cu showed a significant and positive correlation with organic carbon in ($r = 0.3391^*$) Palaviduthi series and ($r = 0.4227$) Irugur series while a non-significant positive correlation was recorded ($r = 0.2668$) in Somayyanur series.

Athokpam *et al.* (2013) analyzing soil macro and micronutrients of Senapati district (rice crop with alluvium, lateritic black regur and red ferruginous soil type), Manipur reported that soil organic carbon was positively and significantly correlated with soil available nitrogen and DTPA extractable micronutrient cations. Available Fe showed positive and significant correlations with pH ($r = 0.8623^{**}$), OC ($r = 0.8355^{**}$), available N ($r = 0.8302^{**}$), available P_2O_5 ($r = 0.7812^{**}$), and also positive and significant correlations with other micronutrient cations. Available Mn showed significant and positive correlation with pH ($r = 0.8938^{**}$), EC ($r = 0.5166^*$), organic carbon ($r = 0.7882^{**}$), available N ($r = 0.7994^{**}$), available P_2O_5 ($r = 0.8364^{**}$), and available K_2O ($r = 0.5402^*$) and also had positive significant correlations with other soil micronutrient cations. Available Zn showed significant and positive correlation with pH ($r = 0.7500^{**}$), organic carbon ($r = 0.7075^{**}$), available N ($r = 0.6897^{**}$), and available P_2O_5 ($r = 0.6874^*$). Available Cu showed significant and positive correlation with pH ($r = 0.8220^{**}$), organic carbon ($r = 0.7422^{**}$), available N ($r = 0.7590^{**}$), available P_2O_5 ($r = 0.7840^{**}$) and available K_2O ($r = 0.5161^*$).

Singh *et al.* (2014) studied soil fertility status of surface soils and correlation of available macro and micronutrients in Chambal region of Madhya Pradesh. A significant and positive correlation of available N was observed with OC ($r = 0.616^*$). Available N was

negatively and significant correlated with pH ($r = -0.210^*$) and EC ($r = -0.288^*$). A significant and positive correlation of available P was observed with OC ($r = 0.507^*$). Available P was significant and negatively correlated with EC ($r = -0.210^*$) and pH ($r = -0.513^*$). A significant and positive correlation of available K was observed between OC ($r = 0.426^*$) and EC ($r = 0.221^*$). Available K showed negative and non-significant correlation with pH ($r = -0.097$) and CaCO_3 ($r = -0.026$). A significant positive correlation of available S was observed between EC ($r = 0.671^*$) and OC ($r = 0.482^*$). Available S was negatively and significantly correlated with pH ($r = -0.593$) and CaCO_3 ($r = -0.196$). Available Zn was positively and significantly correlated with OC ($r = 0.775^*$); negatively and significantly correlated with pH ($r = -0.724^*$) and CaCO_3 ($r = -0.748^*$). Available Fe had significant and positive correlation with OC ($r = 0.489^*$) whereas negative and significant correlation with pH ($r = -0.516^*$) and CaCO_3 ($r = -0.615^*$). Available Cu showed significant and positive correlation with OC ($r = 0.685^*$) whereas negative and significant correlation with pH ($r = -0.710^*$) and CaCO_3 ($r = -0.704^*$). Available Mn showed significant and positive correlation with OC ($r = 0.662^*$) whereas negative and significant correlation with pH ($r = -0.603^*$) and CaCO_3 ($r = -0.669^*$).

2.6 Water quality analysis

2.6.1 Water pH and EC

Sidhu *et al.* (2007) studied the quality of irrigation water in different agro-climatic zones of Trans Gangetic Plain region of Punjab and Haryana states. They noticed that EC ranged from 0.25 to 0.90 and 0.75 to 5.30 $\mu\text{mhos cm}^{-1}$ in Shiwalik foot hills and from 0.45 to 1.05 and 0.5 to 8.0 $\mu\text{mhos cm}^{-1}$ in mid hills of Punjab and Haryana, respectively. In arid plain zone of Punjab EC were 0.20 to 1.80 μmhos

cm^{-1} and that in Haryana ranged from 0.7 to 7.7 $\mu\text{mhos cm}^{-1}$. The quality of irrigation water in foot hills of Shiwalik is good while in mid and Arid Plains Zone water is saline to marginal alkali and saline to moderately alkaline in nature, respectively in both Punjab and Haryana.

Quality of fifty three irrigation waters in coastal areas of Cuddalore and Nagapattinam districts of Tamil Nadu was ascertained by Singaravel *et al.* (2007) and they reported that pH and EC ranged from 7.2 to 9.2 and 0.4 to 8.3 dS m^{-1} , respectively. According to USSL classification 3, 22, and 17 samples were grouped under the classes C_2 , C_3 and C_4 , respectively.

Yadav *et al.* (2007) analyzed composition of fifteen irrigation water samples (tube-wells) which were being used at Hissar in Haryana. They observed that the composition of water varied widely, where the P^H ranged from 7.6 to 8.7 indicating normal to alkaline reaction and EC ranged from 0.75 to 2.30 dS m^{-1} (normal to slightly saline).

Kahlon and Khera (2008) analyzed 488 tube well irrigation water samples of different districts covering three agro climatic zones of Punjab state. They found that EC of irrigation water ranged from 0.68 to 0.82 dS m^{-1} in the Submontane district zone with a mean value of 0.75 dS m^{-1} and pH ranged from 7.57 to 7.69 with a mean value 7.63. EC ranged from 0.50 to 1.16 dS m^{-1} , with mean value 0.74 dS m^{-1} and pH ranged from 7.86 to 9.05 with a mean value of 8.56 in central plain zone, while in south-western districts zone, EC varied from 1.13 to 1.85 with a mean value of 1.49 dS m^{-1} and P^H ranged from 7.88 to 8.93 with a mean value of 8.41, respectively. The data indicated that the underground irrigation water quality was normal in sub mountain zone, medium in central plain zone and poor in south-

western zone. Further, they reported that the use of such groundwater might lead to development of soil salinity and alkalinity in central plain and south-western zones.

Shahid *et al.* (2008) studied the quality of 296 tube wells groundwater samples from 38 villages of Julana block of Jind district, Haryana and found that EC and pH values ranged from 0.27 to 11.0 dS m⁻¹ and 7.04 to 9.90 with mean values of 3.61 dS m⁻¹ and 7.92, respectively. The data indicated that 66.6 per cent water samples had EC < 4 dS m⁻¹, 32.4 per cent had EC 4 to 10 dS m⁻¹ and only 1.0 per cent samples exceeding 10 dS m⁻¹. They further opined that water having EC < 4 dS m⁻¹ could be used with no harmful effect in soil for short term use. However, special management practices are required to be adopted depending soil type, crop growth and climatic factors for groundwater having EC more than 4 dS m⁻¹.

Donga *et al.* (2009) analyzed 56000 samples of water for assessing the quality of ground water used for irrigation in Gujarat and they found that pH of water ranged from 6 to 11.9 with an average value of 7.8. Electrical conductivity ranged from 0.19 to 30.3 dS m⁻¹ with an average value of 1.5 dS m⁻¹, respectively. The data indicated that 20 per cent of the samples had pH value < 7.5 (good water) and 52 per cent samples were under high salinity group.

Joshi and Kulkarni (2009) observed that pH value of water from dams at Nilona, Borgaon and Jamwadi in Yavatmal district of Maharashtra varied from 6.6 to 7.3. All the samples were within permissible limits (6.5 to 8.5) as prescribed by WHO and APHA.

Kirubavathy (2010) studied the ground water quality of Orathupalayam village, Erode district of Tamil Nadu. They observed that the mean value of pH was 7.8 which indicated the alkaline in nature of water. EC of water samples was very high (5250 µmhos cm⁻¹

¹) and exceeded the normal acceptable range ($1000 \mu\text{mhos cm}^{-1}$). It clearly indicated the unsuitability/poor quality of ground water for irrigation purpose.

Tharavathy (2010) analyzed nine groundwater samples in Mangalore city of Karnataka and revealed that pH value of normal water ranged from 6.00 to 10.5 with most of the samples having neutral to slightly alkaline reaction.

2.6.2 SAR and RSC

Sidhu *et al.* (2007) studied the quality of irrigation water in different agro climatic zones of Trans Gangetic Plain region of Punjab and Haryana. They observe that RSC varied from 0 to 0.7 me L^{-1} in Punjab and 0 to 4.60 me L^{-1} in Haryana parts, respectively at Shiwalik foot hills indicating good quality of irrigation water for growing crops. In mid hills, it ranged from 0.5 to 2.0 me L^{-1} in Punjab and 0 to 10.6 me L^{-1} in Haryana part whereas, in arid plain zone, it ranged from 0 to 10.80 me L^{-1} and 0 to 7.50 me L^{-1} in Punjab and Haryana parts, respectively indicating increase in deterioration of irrigation water quality.

Yadav *et al.* (2007) analyzed composition of fifteen irrigation water samples (tube-well) which are being used at Hisar in Haryana. They observed that the SAR and RSC ranged from 3.7 to 19.5 (mmole L^{-1})^{1/2} and 0.4 to 10.8 me L^{-1} , respectively. Out of fifteen water samples, three water samples had SAR $>10 (\text{mmole L}^{-1})^{1/2}$ and seven water samples had RSC $>2.5 \text{ me L}^{-1}$, respectively.

Kahlon and Khera (2008) analyzed 488 tube well water samples from three agro climatic zones of Punjab and found that in Submontane districts zone RSC of water ranged from 1.1 to 1.86 with a mean value of 1.48 me L^{-1} . In the central plain districts zone, RSC ranged from 1.79 to 3.07 with a mean value of 2.71 and in south-

western zone 3.10 to 3.44 with a mean value of 3.27 me L⁻¹, respectively. The data exhibited that underground irrigation water quality was normal in sub mountain zone, medium in central plain zone and poor in south-western zone on the basis of suitability of RSC.

Shahid *et al.* (2008) reported that SAR and RSC of water samples ranged from 0.20 to 12.73 (m mol L⁻¹)^{1/2} and 0.00 to 14.0 me L⁻¹ with a mean value of 5.34 (m mol L⁻¹)^{1/2} and 2.71 me L⁻¹, respectively. They categorized 18 per cent water samples as good, 31 per cent marginally saline, 25 per cent saline, 9 per cent high SAR-saline, 8 per cent alkaline and 1 per cent highly alkaline, based on EC, SAR and RSC.

Donga *et al.* (2009) analyzed 56000 water samples for the quality of ground water used for irrigation in Gujarat and they found that SAR values in 61 per cent waters were in the normal group, 30 per cent in low salinity, 7 per cent as medium saline and 2 per cent under high salinity category, while, RSC value was negative (-2.0) and 74 per cent of water samples were in the safe range leaving 26 per cent as 15 per cent marginal and 11 per cent unsafe.

MATERIALS AND METHODS



III. MATERIALS AND METHODS

The materials used and methodologies followed for achieving the objectives mentioned in chapter-I, are described in this chapter.

3.1 Research Material

This is being study on “soil fertility status of paddy and sugarcane growing areas of Butlaw and Dabhalia villages of Navsari district” the geographical setting of the selected study area is described here.

3.1.1 Location and extent

Gujarat state is situated on the west coast of India and lies between 20°01' and 24°00' North Latitude and 68°04' and 74°04' East Longitude. The State has a geographical area of 19,6117 km². Navsari district is located between 20°07' and 21°00' North Latitude and 72°43' and 73°00' East Longitude. The district is located in the south-eastern part of Gujarat state in the coastal low land along Purna river. The total geographical area of Navsari district is 2,657.56 km². Total population of Navsari district is 1,330,711 according to 2011 census. The district has six talukas (Navsari, Jalalpore, Gandevi, Chikhli, Khergam and Bansda). The district abounds in rice and sugarcane fields, sapota plantations, and mango trees. There are 65 villages in Navsari taluka of Navsari district, out of these villages named “Butlaw” and “Dabhalia” was selected as the site for the present study (Fig. 3.1). The village map showing polygons as well as survey numbers are also presented here for both the village (Fig. 3.2, 3.3, 3.4 and 3.5).

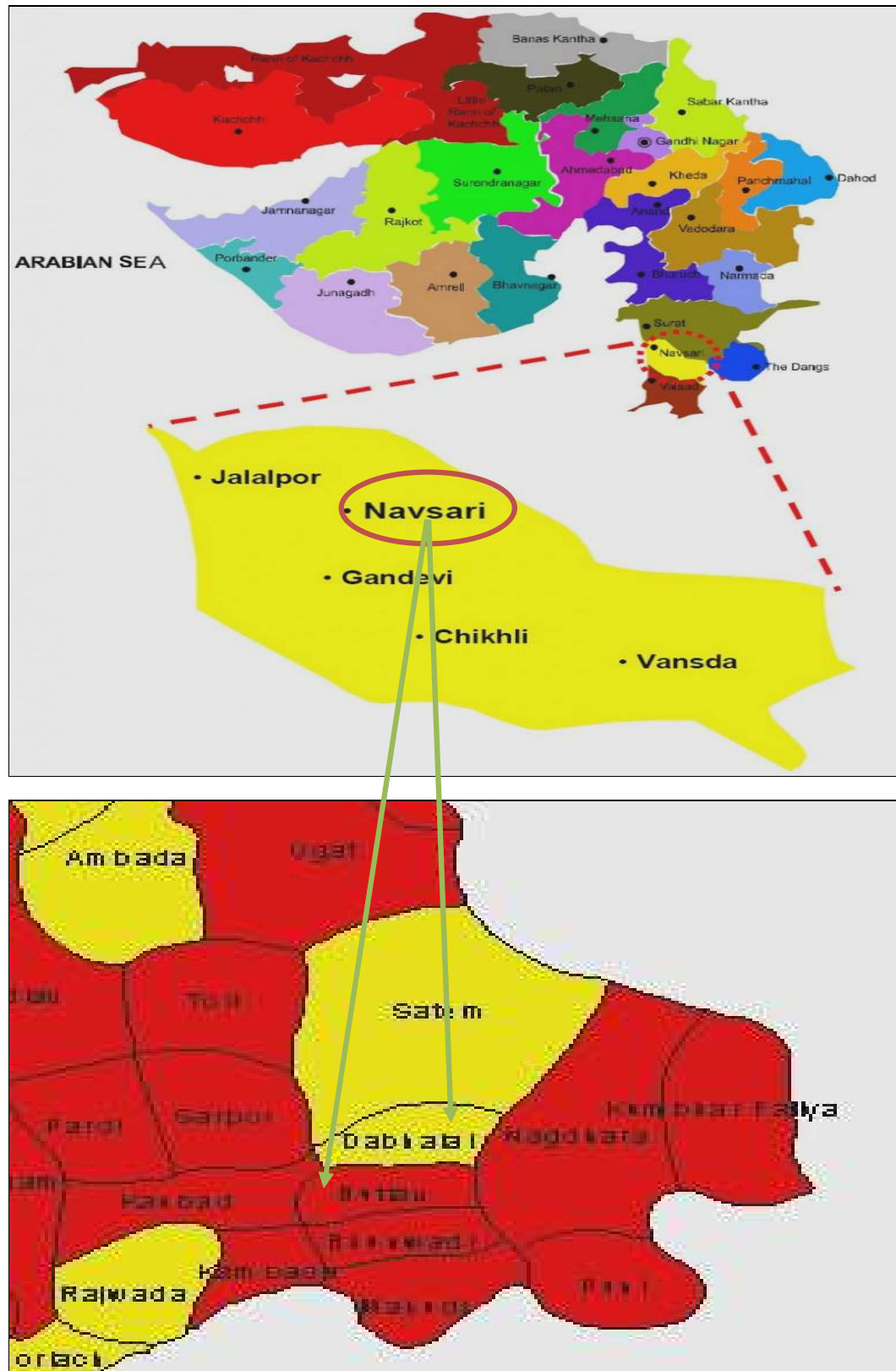
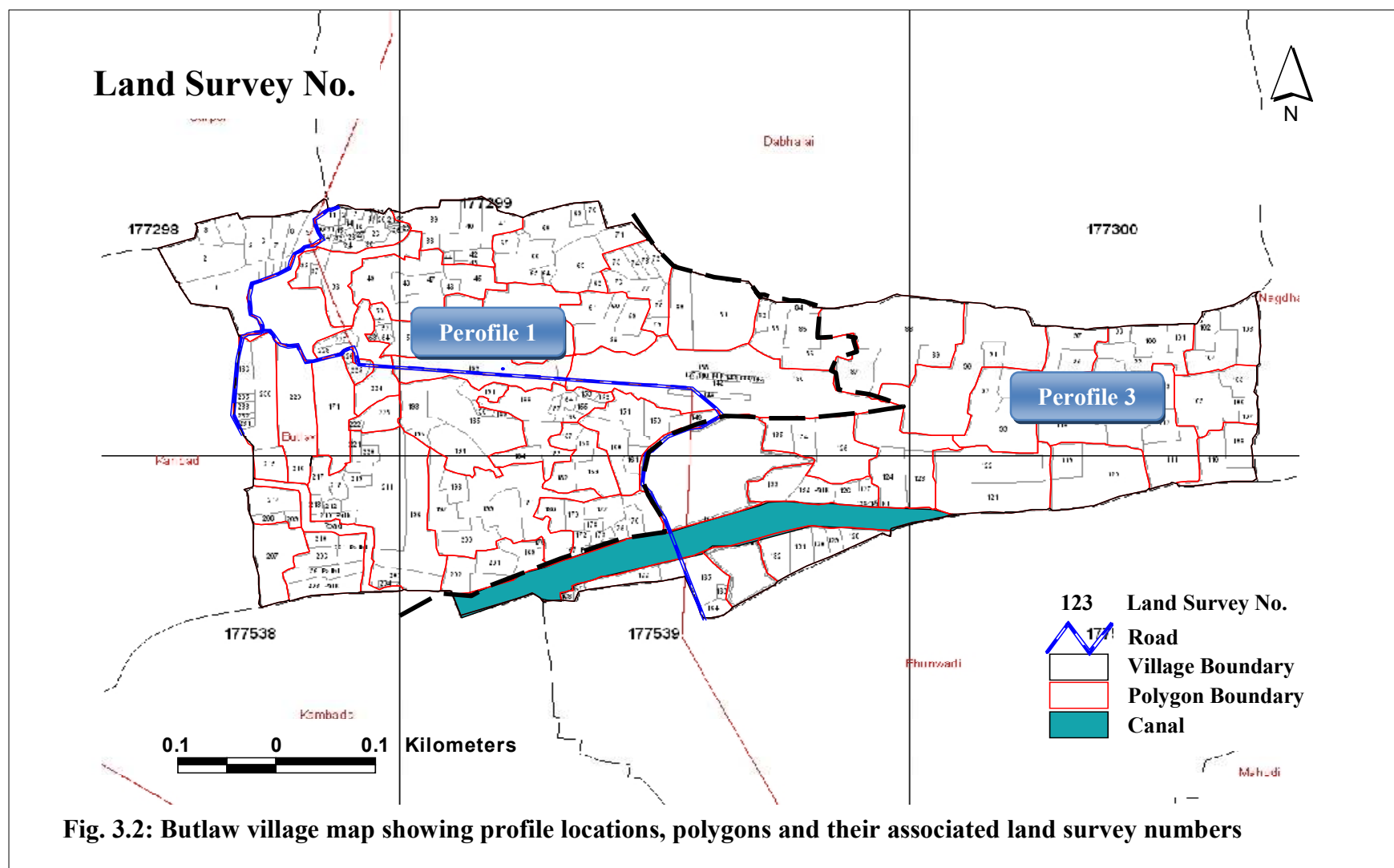
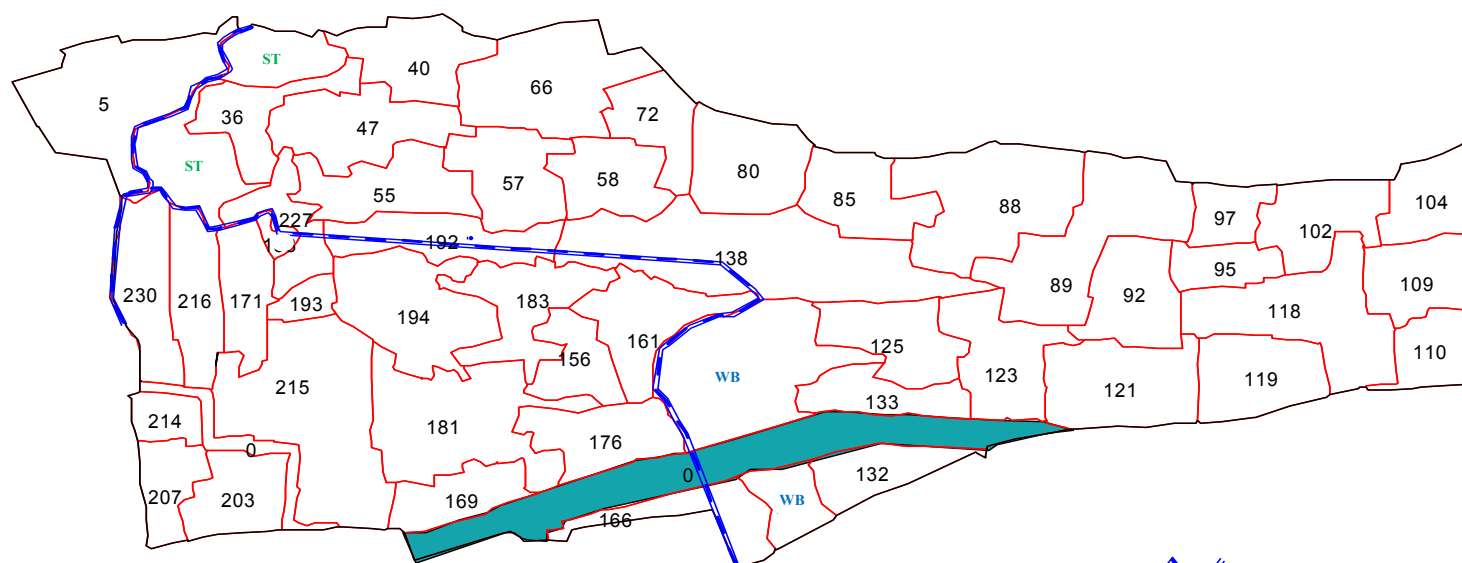


Fig. 3.1: Location map of the study area



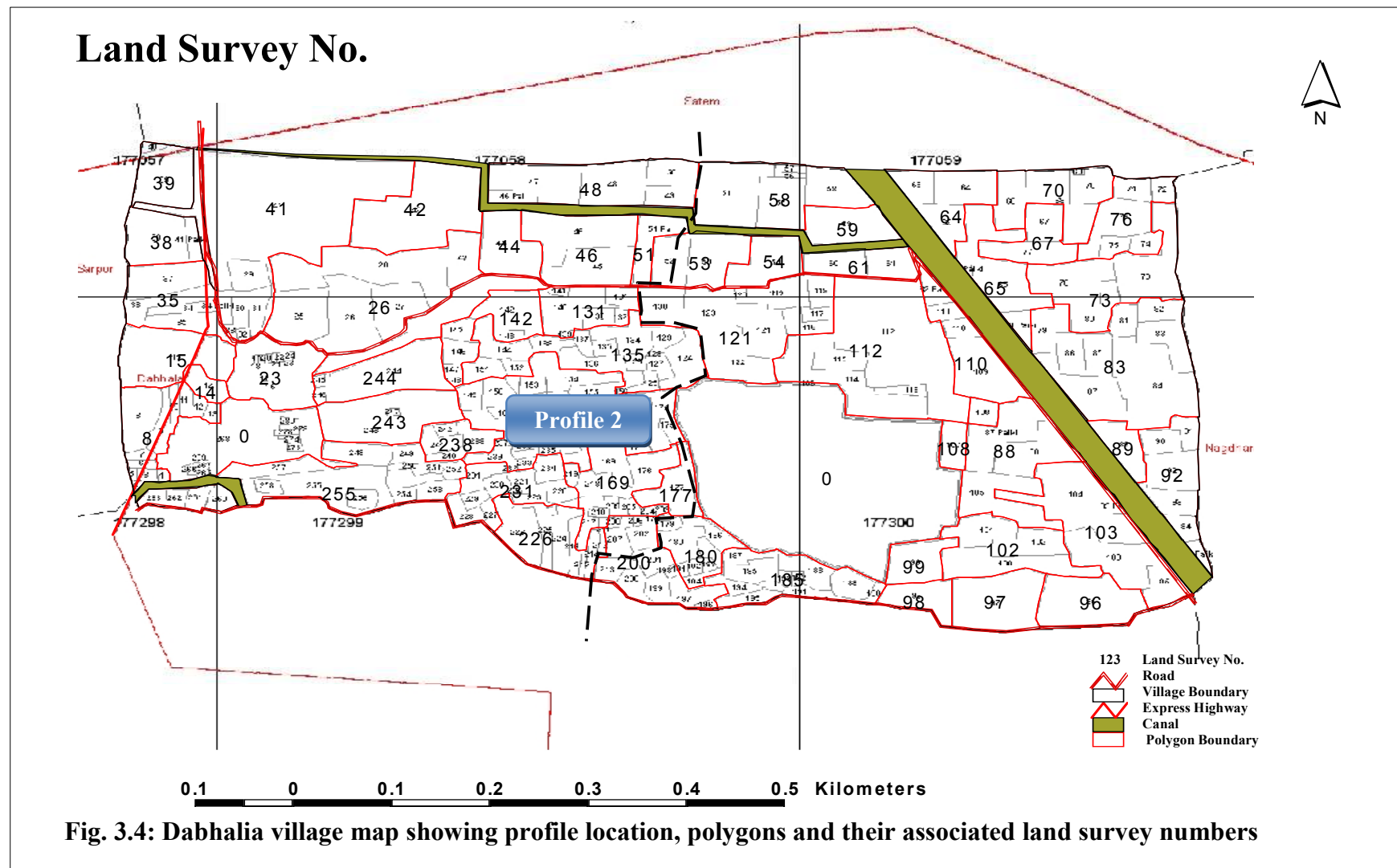
Polygon ID No.



0.1 0 0.1 0.2 0.3 Kilometers

-  Road
-  Village Boundary
-  Polygon Boundary
-  Canal
-  ST Settlements
-  WB Water Body
-  123 Polygon ID No.

Fig. 3.3: Butlaw village map of showing polygons and their boundary



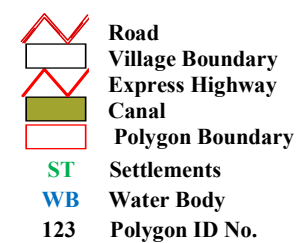
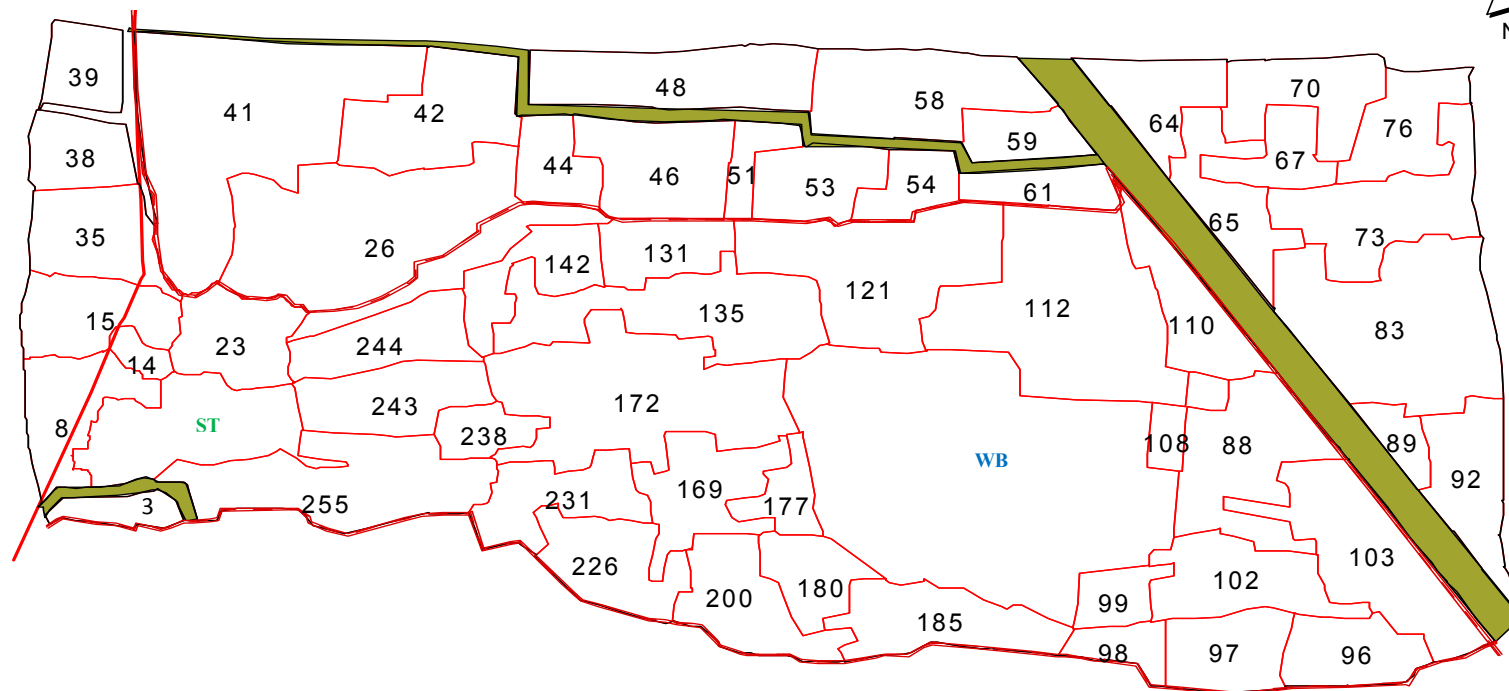


Fig. 3.5: Dabhalia village map showing polygons and their boundary

3.1.2 Physiography, relief and drainage

The land forms occurring in the study area are nearly leveled to very gently sloping alluvial plain made up of trap origin alluvium. The general slope of the area is from North-East to South-West. The land is nearly leveled (0-1 %) to gently sloping (1-3 %) in uplands and leveled to nearly level in low lands. The soils of upland are well drained but are subjected to moderately restricted permeability whereas the low land soils are imperfectly drained with restricted permeability.

3.1.3 Geology

Geologically this is very young region. Accumulation of volcanic rocks principally formed by basaltic lava known as Deccan Trap is the single most important and extensive geological formation. The plain is formed as a result of recent alluvium of trap origin. The recent deposits carried by the westerly flowing rivers have developed black cotton soils also known as 'regurs'. The depth varies from around 1 m to as much as 10 m. They contain 40 to 70 per cent clay dominated by smectite group of clay minerals. They are neutral to alkaline in reaction.

3.1.4 Climate

The climate of the area is sub-humid with the mean annual rainfall of about 1623 mm. Out of the total rainfall, 97 per cent is received during south-west monsoon from June to September. The number of rainy days varies between 45 and 55. The area being located in coastal belt, owing to maritime influence shows more equitable temperature round the year with monthly temperature during the year is lowest in the January and thereafter increases continuously and reaches to its highest value in May. From humidity point view, not much variation in relative humidity is observed during morning hours, but the variation is much more in the evening hours. On an average, the

humidity is minimum during January and February and it reaches to maximum during monsoonic months. The sunshine hours are minimum during the monsoonic months and maximum during summer months. The annual sunshine hour worked out to be 7.8. Though, the selected area belongs to coastal ecosystem, yet the annual average wind speed is only 5.1 km hr^{-1} , which is quite low in the context of location of the area.

3.1.5 Crops

In the study area, paddy and sugarcane are the most preferred crop, followed by spider lili and vegetable crops. Green manuring after sugarcane crop also followed. Mango and sapora are the horticultural crops most commonly grown in the area.

3.1.6 Natural vegetation

In addition to climate, soil and water, the vegetation existing in the area was also recorded. The area under forest is absent, but most of the barren fields are occupied by *Prosopis juliflora* and *Phoenix sylvestris*. While traversing the area during soil survey, individual species on the field boundaries and waste lands were identified and recorded with help of scientists from forestry.

3.2 Research Methodology

The scientific research methodologies followed in the study for characterization of soil and ground water are described in this part.

3.2.1 Survey

3.2.1.1 Soil Profile

During initial traversing different land forms having identical topography, soil type *etc.* was marked on the cadastral maps of the villages. Based on landform profiles were excavated at the representative spots by following the prescribed procedure (Soil

Survey Staff, 2006) and subsequently, horizon wise soil samples were collected. Along with this, the soil survey form prescribed by NBSS & LUP (1990), Nagpur was also filled by recording the physical features, vegetation, colour, present land use *etc.* For estimating bulk density and particle density, horizon wise soil sample were collected with the help of core sampler. In all, 3 profiles were exposed from which total of 14 numbers of horizon wise sample were obtained.

3.2.1.2 Base map

Cadastral maps of Butlaw and Dabhalia village procured from land survey office were merged according to the adjoining boundaries. During initial survey, according to land use and elevation of different nearby survey numbers were identified and grouped as a polygon and the polygon identification numbers were given. Further polygons were grouped based on representing profile-area wise.

3.2.1.3 Surface and sub-surface soils

Grid areas were selected based on relative elevation of nearby survey numbers and land use. In order to characterize soil resource, the whole area was divided as a grid point, representing approximately 1.5 to 2.5 ha area. The representing grid point areas were clubbed and polygon ID for grid was generated. From each grid point soil samples were collected at a depth of 0-20 and 20-40 cm by adopting standard procedure (Anon., 1971). Similarly, the latitude, longitude along with altitude was also recorded for each sample point with the help of portable geo-positioning system (GPS Garmin). In all, during September 2016, 102 soil samples were collected from the selected area (102 x 2 depth = 204).

3.2.1.4 Processing of soil samples

All the surface, sub-surface and profile soil samples were air dried and ground to pass through 2.0 mm sieve. The processed soil

samples were preserved in polyethylene bags for analysis purpose. The necessary care was taken to avoid the contamination of micronutrients.

3.2.1.5 Classification of soils

After recording physiographic features during survey and subsequent to this, physical and chemical properties of collected soil samples were determined. Based on these values, soils were classified with the help of NBSS and LUP, Regional Centre, Udaipur, Rajasthan.

3.2.2 Ground water

While collecting soil samples, ground water samples were also collected from the bore wells and tube wells which are being used for irrigation purpose. From the whole study area in all 30 water samples were collected during pre monsoon and post monsoon seasons by following standard procedure and preserved for chemical analysis.

3.2.3 Climate

The daily data of rainfall, minimum and maximum temperature, morning and evening relative humidity, sunshine hours and wind velocity for past 30 years were collected from the Department of Meteorology, N. M. College of Agriculture, NAU, Navsari, which is in the vicinity of selected study area. The rainfall data was subjected to standard deviation, trend of South-West monsoon, seasonal distribution and probability analysis (FAO, 1977). For remaining parameters, monthly means were computed and graphical trends were obtained. Using these data as well as NBBS and LUP data (Mandal *et al.*, 1999), a hydrograph was also prepared for judging the length of growing period as per the procedure described by Haggin and Kasam (1981).

3.2.4 Natural vegetation

During soil survey, the natural vegetation existing on the field bunds, canal sides, fallow fields, barren areas *etc.* was also noted with the help of Agroforestry scientists. Apart from this, there was some

tree/shrub species which could not be identified on field, samples of the same were brought to ASPEE College of Horticulture and Forestry, NAU, Navsari for identification. After completion of survey, botanical name and uses of each species were recorded through discussion with either local people or scientist or literature.

3.2.5 Land use pattern

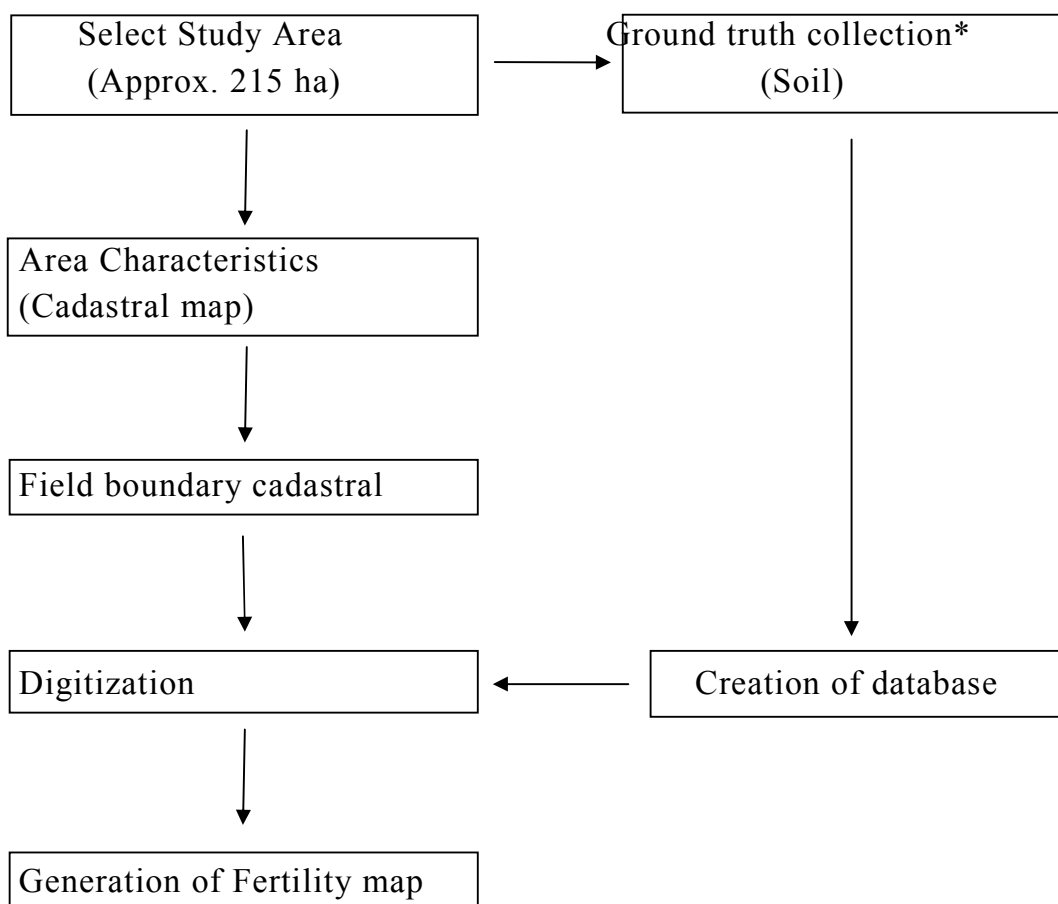
While traversing for land form identification and soil sample collection from the grid points, existing land use of the surrounding area was also recorded. Major features like, settlement, water bodies, canals, creek, roads *etc.* were also marked and their exact position was noted with the help of GPS.

3.2.6 Generation and integration of thematic maps

UMAX, ASTRA 610 scanner was used to convert the cadastral maps of the villages in to digital format and all the maps were spread in different files. All the scanned maps were digitized on screen in Arc View, a raster based GIS software and stored in vector format as different layers. The digitized maps were geo referenced and transformed from the computer coordinates to the real world coordinates using polyconic projection, by selecting ground control points for each of the maps and the total Root Mean Square error was found to be very small (0.94) indicating high accuracy of the rectification.

Similarly, land form wise soil related properties, water resources and land use values were stored in different layers having distinct polygon ID number. Subsequently, separate thematic maps were prepared for important features of the study area. In order to know the interactive effect of pertinent properties, different thematic maps were integrated using GIS based Arc View 3.2a software. For easy understanding, the above methodology is presented in flow chart.

Flow chart:



*Standard procedures as directed NBSS&LUP was followed

**Table 3.1: Details of representative profile number wise sample location and land use
PN#1 Butlaw village (n=28)**

Polygon ID No.	Latitude (N)	Longitude (E)	Elevation (ft)	Survey No.	Land use
5	20°54'35.38"	73°04'12.82"	100	1 to 9	Mango
36	20°54'36.51"	73°04'18.72"	93	35 to 37	Sugarcane
40	20°54'41.07"	73°04'24.18"	106	38 to 44	Rice
47	20°54'36.31"	73°04'25.27"	95	45 to 49	Sugarcane
55	20°54'30.47"	73°04'24.24"	96	50 & 56	Spider Lily
57	20°54'41.09"	73°04'35.71"	97	57	Sugarcane
66	20°54'34.91"	73°04'32.85"	95	62 to 71	Rice
58	20°54'39.39"	73°04'30.21"	98	68, 69 & 70	Rice
72	20°54'36.08"	73°04'40.38"	101	72 to 77	Spider Lily
80	20°54'32.90"	73°04'43.91"	96	80 & 81	Rice
138	20°54'28.42"	73°04'39.07"	101	137 to 148	Sugarcane
156	20°54'33.24"	73°04'39.61"	94	157 to 158 & 182	Rice
161	20°54'21.52"	73°04'38.59"	96	149 to 151, 160 & 161	Rice
169	20°54'14.85"	73°04'34.09"	102	169, 201 & 202	Rice
171	20°54'24.78"	73°04'16.81"	96	171	Sugarcane
176	20°54'16.67"	73°04'38.91"	103	172 to 180	Rice
181	20°54'18.54"	73°04'33.60"	100	181, 197 to 200	Rice
183	20°54'18.29"	73°04'31.90"	98	152 to 156, 184, 187 & 188	Sugarcane
192	20°54'28.91"	73°04'28.41"	92	192	Sugarcane
193	20°54'27.02"	73°04'22.36"	95	222 & 223	Rice
194	20°54'24.56"	73°04'24.44"	95	185, 189, 190 & 193 to 195	Rice
203	20°54'12.55"	73°04'26.29"	101	203, 206 & 210	Sugarcane
207	20°54'12.63"	73°04'15.61"	90	207	Sugarcane
214	20°54'19.32"	73°04'15.80"	92	208, 209 & 214	Sugarcane
215	20°54'18.99"	73°04'15.50"	95	210 to 213, 217 to 222 & 196	Sugarcane
216	20°54'24.26"	73°04'14.64"	96	229	Rice
227	20°54'28.92"	73°04'19.02"	100	225 to 228	Rice
230	20°54'24.59"	73°04'16.70"	95	186, 205, 215 & 230 to 233	Rice

Contd...

PN#2 Dabhalia Village (n=27)

Polygon ID No.	Latitude (N)	Longitude (E)	Elevation (ft)	Survey No.	Crop
3	20°54'38.91"	73°04'22.41"	100	260 to 262	Paddy
8	20°54'46.97"	73°04'18.76"	101	1 to 13	Mango
14	20°54'49.27"	73°04'22.24"	95	14	Sugarcane
15	20°54'50.20"	73°04'20.15"	95	15	Sugarcane
23	20°54'47.11"	73°04'25.94"	110	16 to 24	Mango
26	20°54'52.83"	73°04'31.24"	104	25 to 28 & 43	Mango
35	20°54'53.18"	73°04'22.09"	91	34 to 37	Spider Lily
38	20°54'58.76"	73°04'19.52"	92	38	Spider Lily
39	20°55'02.52"	73°04'20.72"	99	39	Sugarcane
41	20°55'02.87"	73°04'25.46"	100	29 to 33 & 44	Sugarcane
42	20°55'00.17"	73°04'34.56"	99	42	Rice
44	20°54'58.26"	73°04'40.78"	102	44	Rice
46	20°54'59.83"	73°04'46.77"	105	45 & 46	Rice
48	20°55'02.41"	73°04'46.96"	102	47, 48, 49 & 50	Rice
51	20°55'01.72"	73°04'52.99"	106	51	Rice
131	20°54'54.89"	73°04'47.86"	102	131 to 133 & 139 to 141	Rice
135	20°54'51.73"	73°04'46.08"	99	124 to 129, 134 to 138, 144 & 151 to 152	Spider Lily
142	20°54'53.69"	73°04'42.26"	99	143 & 145 to 148	Sugarcane
169	20°54'41.45"	73°04'45.56"	97	169, 176, 219, 218, 203 to 205, 209, 210, 217 & 218	Rice
172	20°54'45.00"	73°04'47.62"	100	149, 150, 153 to 155, 157 to 175, 232 to 237 & 239	Spider Lily
177	20°54'41.68"	73°04'50.86"	101	177	Rice
226	20°54'37.76"	73°04'40.43"	103	212 to 216 & 224 to 226	Spider Lily
231	20°54'41.00"	73°04'36.16"	97	220 to 223 & 227 to 231	Spider Lily
238	20°54'44.90"	73°04'36.44"	102	238 to 242	Spider Lily
243	20°54'48.95"	73°04'34.80"	100	243	Mango
244	20°54'50.62"	73°04'34.99"	102	244 to 246	Sugarcane
255	20°54'39.58"	73°04'26.68"	101	248 to 258	Rice

Contd...

PN#3 Butlaw village (n= 19) and Dabhalia village (n= 28)

Butlaw village (n= 19)					
Polygon ID No.	Latitude (N)	Longitude (E)	Elevation (ft)	Survey No.	Crop
88	20°54'32.07"	73°04'56.56"	108	88 to 89	Sugarcane
89	20°54'29.19"	73°04'58.87"	105	90 & 91	Rice
92	20°54'24.00"	73°05'02.32"	105	93 to 94	Spider Lily
95	20°54'26.27"	73°05'08.18"	106	95	Rice
97	20°54'30.09"	73°05'07.85"	105	96 & 97	Rice
102	20°54'29.47"	73°05'13.64"	107	98 to 101, 114 & 115	Rice
104	20°54'30.96"	73°05'20.66"	104	102 to 104	Rice
109	20°54'26.38"	73°05'17.54"	105	105 to 107 & 109	Rice
110	20°54'21.21"	73°05'16.05"	104	108 & 110	Rice
118	20°54'25.38"	73°05'13.53"	103	112, 113 & 116 to 118	Rice
119	20°54'20.50"	73°05'10.52"	108	119 & 120	Mango
121	20°54'19.06"	73°05'05.47"	104	121 & 122	Mango
123	20°54'20.51"	73°04'58.38"	105	123 & 124	Nilgiri
125	20°54'23.27"	73°04'49.02"	103	125	Spider Lily
132	20°54'14.89"	73°04'48.32"	102	128 to 132	Sugarcane
133	20°54'19.38"	73°04'47.61"	101	126 to 128 & 132	Rice
165	20°54'13.92"	73°04'36.146"	102	163, 164 & 165	Rice
166	20°54'13.05"	73°04'37.18"	102	163 to 168	Rice
215	20°54'18.99"	73°04'15.50"	95	196, 203 to 204, 210 to 213 & 217 to 221	Sugarcane
Dabhalia village (n= 28)					
53	20°55'56.25"	73°04'52.46"	107	51, 52 & 53	Rice
54	20°54'56.43"	73°04'57.14"	106	54	Rice
58	20°55'20.31"	73°04'59.86"	99	51 & 55 to 58	Sugarcane
59	20°54'59.69"	73°05'01.63"	98	59	Rice
61	20°54'56.70"	73°05'03.59"	101	60 & 61	Rice
64	20°55'01.89"	73°05'05.23"	100	62, 63 & 64	Rice
65	20°54'56.94"	73°05'08.24"	103	65	Rice
67	20°54'59.34"	73°05'12.65"	106	67 & 71	Rice

Contd...

Polygon ID No.	Latitude (N)	Longitude (E)	Elevation (ft)	Survey No.	Crop
70	20°55'02.88"	73°05'13.78"	112	66, 68 & 70	Sugarcane
73	20°54'55.03"	73°05'17.83"	105	72, 73, 78 & 80	Sugarcane
76	20°54'00.04"	73°05'18.84"	111	71 to 72 & 74 to 76	Sugarcane
83	20°54'52.25"	73°05'20.01"	107	79 & 81 to 87	Rice
88	20°54'43.54"	73°05'11.94"	102	88, 105 & 107	Sugarcane
89	20°54'45.30"	73°05'16.02"	102	89	Sugarcane
92	20°54'44.37"	73°05'18.94"	103	90 to 95	Rice
96	20°54'32.28"	73°05'16.54"	105	96	Sugarcane
97	20°54'32.01"	73°05'09.17"	105	97	Sugarcane
98	20°54'33.35"	73°05'03.66"	103	98	Rice
99	20°54'35.90"	73°04'04.45"	102	99	Spider Lily
102	20°54'37.18"	73°04'11.45"	99	100 to 102	Sugarcane
103	20°54'36.17"	73°04'17.34"	105	103, 104 & 95	Sugarcane
108	20°54'48.12"	73°05'08.12"	106	108	Rice
110	20°54'51.47"	73°05'07.95"	105	109 to 111	Sugarcane
112	20°54'52.41"	73°05'03.78"	103	108, 112 to 115 & 106	Sugarcane
121	20°54'52.30"	73°04'56.01"	105	116 to 123 & 130	Rice
180	20°54'36.24"	73°04'52.55"	98	180 & 186	Rice
185	20°54'35.52"	73°04'55.64"	99	185 & 187 to 194	Rice
200	20°54'33.45"	73°04'47.79"	100	195 to 202, 206 to 208 & 213	Rice

3.2.7 Analytical procedures for soil and water analysis

The methods followed for determining different soil and water parameters are given here along with corresponding references.

3.2.7.1. Methods of soil analysis

All the soil samples were analyzed for physical as well as chemical properties by using following standard methods as mentioned below

3.2.7.1.1 Physical properties of soil

Soil depth

The depth of soil at different physiographic situation from upper to lower elevation of the village was assessed by using different types of auger, spade, kudali and khurpi, *etc.* during field traversing, depth of each representative pedons including their horizons was actually measured by 'standard measuring tape'.

Soil colour

Soil colour as well as colour of mottling (if any) was noted with the help of Munsel colour chart for both dry as well as wet condition of soil (Piper, 1950).

Mechanical analysis

Soil mechanical analysis was done by International pipette method in laboratory as described by (Piper, 1950).

Texture

Soil texture class obtained in the laboratory by mechanical analysis of soil on the basis of the sand, silt and clay percentage following USDA textural classification chart (Gupta, 2007).

Structure

The soil structure which refers the aggregation of primary soil particles into compound particles was designated as grades, class and type of soil by rupturing the soil mass across natural surfaces of weakness (Soil Survey Manual, 1951).

Consistency

The soil consistency *i.e.*, hardness of soil when dry, firmness when moist and stickiness and plasticity at wet condition from surface soils as well as different horizons of pedons was measured by hand feeling method (Soil Survey Manual, 1951).

Bulk density

The bulk density of soil was determined by core method as described by Black *et al.* (1965).

Particle density

The Particle density of soil was determined by relative density bottle method as described by Black *et al.* (1965).

Porosity

Porosity of soil was determined by using computation formula given by Richards (1954).

Roots

The size and quantity of plant roots at varying depths of pedons were observed by using magnifying lens and recorded accordingly.

Soil moisture constants (< 2mm fraction)

Soil moisture at 1/3 bar and 15 bar were determined by using Pressure plate apparatus as described by Richards (1954).

Available water capacity

Available water capacity in soils was computed by subtracting the quantity of water held at 15 bar from that at 1/3 bar. It was expressed as w/w per cent.

Water stable aggregates

Part of air dried original undisturbed and ungrounded samples (each horizon) were passed through 5 mm sieve for estimating aggregate size distribution by wet sieving method (Yoder, 1936) by using a set of sieves having pore diameter of >2.0, 1.0, 0.5, and 0.25 mm for the measurement of the distribution of water stable aggregate percentage.

3.2.7.1.2 Chemical properties of soil

Soil pH_(1:2.5)

Soil pH_{2.5} was measured in 1:2.5 soils: water suspension by using glass electrode electric pH-meter (Jackson, 1967).

Table 3.2: The ratings for soil pH (Patel, 2001)

Sr. No.	Ratings	pH Range
I	Normal	6.5 - 7.5
II	Slightly alkaline	7.5 – 8.5
III	Moderately alkaline	8.5 – 9.5

Electrical Conductivity EC_(1:2.5) and ECe

Electrical conductivity of 1:2.5 soil: water suspension (EC_{2.5}) was estimated in by electrical conductivity meter (Jackson, 1967).

Electrical conductivity of saturation extract (ECe) was also determined following the method described by Jackson (1967).

Table 3.3: The ratings for soil electrical conductivity (Patel, 2001)

Sr. No.	Ratings	EC range (dS m ⁻¹)
I	Non saline	< 1.0
II	Slightly saline	1.0-2.0
III	Moderately Saline	2.0-3.0
IV	Highly saline	> 3.0

Soil organic carbon (SOC)

Soil organic carbon was determined by following Walkley and Black rapid titration method (Jackson, 1967).

Table 3.4: The ratings for soil organic carbon content (Walkley and Black, 1934)

Sr. No.	Ratings	OC range (%)
I	Low	<0.50
II	Medium	0.50-0.75
III	High	>0.75

Available nitrogen

Soil available nitrogen was determined by using alkaline potassium permanganate method (Subbiah and Asija, 1956).

Table 3.5: The ratings for soil available N content (Subbiah and Asija, 1956)

Sr. No.	Ratings	Available N range (kg ha ⁻¹)
I	Low	< 250
II	Medium	250-500
III	High	>500

Available P

Soil available phosphorus was determined by following Spectrometric (Extraction with 0.5M NaHCO₃, pH 8.5) method (Olsen *et al.*, 1954).

Table 3.6: The Rating for soil available P₂O₅ content (Patel, 2001)

Sr. No.	Ratings	Available P ₂ O ₅ (kg ha ⁻¹)
I	Low	<22.9
II	Medium	22.9-57.25
III	High	>57.25

Available potassium

Soil available potassium was determined by following flame photometric (extraction with 1N NH₄ OAc) method (Jackson, 1967).

Table 3.7: The ratings for soil available K₂O content (Hanway and Heidel, 1952)

Sr. No.	Rating	Available K ₂ O (kg ha ⁻¹)
I	Low	<140
II	Medium	140-280
III	High	>280

Available sulphur

Available sulphur was determined by using 0.15 per cent CaCl₂ solution (Willams and Steinbergs, 1959).

Table 3.8: The ratings for soil available S content (Hariram and Dwivedi, 1994)

Sr. No.	Rating	Available S (mg kg ⁻¹)
I	Low	<10
II	Medium	10-20
III	High	>20

Exchangeable Na⁺ and K⁺

Exchangeable Na⁺ and K⁺ were determined using neutral normal ammonium acetate extractant by flame photometer (Jackson, 1967).

Exchangeable Ca⁺⁺ and Mg⁺⁺

Exchangeable Ca⁺⁺ and Mg⁺⁺ were determined using neutral normal ammonium acetate extractant by EDTA-titration versenate method (Jackson, 1967).

Cation exchange capacity (CEC)

Cation exchange capacity of soil was evaluated by subtracting summation of water soluble bases from summation of neutral normal ammonium acetate extracted bases (Black *et al.* 1965).

Exchangeable sodium percentage

Exchangeable sodium percentage was computed by dividing exchangeable Na⁺ ions by CEC of soil and multiplying the same with 100.

Free Calcium carbonate

It was determined by neutralization with an acid (Piper, 1950).

Available (DTPA Extractable) micronutrients

DTPA - extractable Fe, Mn, Zn, Cu, were determined from soil samples by using atomic absorption spectrophotometer the method as suggested by Lindsay and Norvell, (1978).

Table 3.9: The ratings for soil available Micronutrients (Lindsay and Norvell, 1978)

Sr. No.	Available micronutrients (mg kg ⁻¹)	Ratings		
		Deficient	Marginal	Adequate
I	Iron (Fe)	<5	5-10	>10
II	Manganese (Mn)	<5	5-10	>10
III	Zinc (Zn)	<0.5	0.5-1.0	>1.0
IV	Copper (Cu)	<0.2	0.2-0.4	>0.4

3.2.7.2 Water analysis

Water samples (tubewell/borewell/openwell) were analyzed for different parameters like pH, EC, cations (Ca²⁺, Mg²⁺, Na⁺ and K⁺), anions (CO₃²⁻ and HCO₃⁻) following the method of Richards (1954). Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were computed as described by him. After analysis, data were tabulated and results were interpreted and discussed thoroughly as required.

3.2.8 Computation and Classification of Nutrient Index

Nutrient Indices for soils were worked out as per the following formula given by Parker *et al.* (1951).

$$\text{Nutrient Index} = \frac{\{(L \times 1) + (M \times 2) + (H \times 3)\}}{\text{Total number of samples}}$$

Where, L=No. of samples under low category, M=No. of samples under medium category and H=No. of samples under high category.

Table 3.10: The ratings for nutrient index (Ramamoorthy and Bajaj, 1969)

Sr. No.	Ratings	Nutrient index
I	Low	<1.67
II	Medium	1.67-2.33
III	High	>2.33

3.2.9: Soil site suitability evaluation

The suitability of a given piece of land is its natural ability to support a specific purpose. Soil site suitability classification was done for the study area by following the framework of land evaluation (FAO, 1976)

Paddy and Sugarcane are the main crops of the selected study area, so the crop suitability evaluation was done for both the crops. Soil-site suitability criteria (crop requirements) for paddy crop given by NBSS & LUP (1990) and soil-site suitability criteria for sugarcane crop as given by Naidu (1999) are followed.

Table 3.11: Soil-site suitability criteria (crop requirements) for paddy

Soil-site characteristics			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climate regime	Mean temperature in growing season	°C	30-34	35-38 21-29	29-40 15-20	>40 <15
	Total rainfall	mm	1110-1250	900-1110	750-900	<750
Land quality	Land Characteristics					
Oxygen availability to roots	Soil drainage	Class	Imperfectly drained	Moderately drained	Well drained	Excessively drained
	Free from flooding	Month	>4	3-4	2-3	
	Depth of water	cm	<10	10-20	20-40	>40
Nutrient availability	Texture	Class	c, sic, cl, sil & sc	scl, sil & l	sl & ls	s
	pH	1:2.5	5.5-6.5	6.4-7.5 4.5-5.4	7.6-8.5	>8.5 <4.5
	CEC	cmol (p ⁺) kg ⁻¹	>20	10-20	10-5.0	<5.0
	CaCO ₃ in root zone	%	<15	15-20	25-30	>30
Rooting conditions	Effective soil depth	cm	>75	51-75	25-50	<25
Soil toxicity	Salinity (ECe)	dS m ⁻¹	<2.0	2.0-4.0	4.0-9.0	>9.0
	Sodicity (ESP)	%	<15	15-40	40-50	>50
Erosion hazard	Slope	%	0-1	1-3	3-5	>5
Note: s- sand; ls- loamy sand; sl- sandy loam; scl- sandy clay loam; cl- clay loam; sil- silt loam; l-loam; sic- silty clay; sc-sandy clay; c- clay, Source: NBSS & LUP (1990)						

Table 3.12: Soil-site suitability criteria (crop requirements) for sugarcane

Soil-site characteristics			Rating			
		Unit	Highly suitable S1	Moderately suitable S2	Marginally suitable S3	Not suitable N
Climate regime	Mean temperature in growing season	°C	30-34	26-29 35-38	25-20 39-40	<20 >40
	Mean minimum temperature in growing season	°C	10-20	21-30	9-5	<5
	Mean RH (%) in	Growing season	70-85	60-70/85-90	60-70/>90	<50
		Ripening season	55-76	75-90	<55/>90	-
Land quality	Land characteristics					
Oxygen availability to roots	Soil drainage	Class	Well drained	Moderately drained	Poorly drained	Very poorly/ excessively drained
	Depth of water	M	>1.0	1.0-0.5	<0.5	
Nutrient availability	Texture	Class	l, cl, sil, silcl, sc & scl	c(m/k) & sl	c(ss)	
	pH	1:2.5	7.8-0-8.0	6.0-6.9 8.1-9.0	4.0-5.9 9.1-9.5	<4.0 >9.5
	CEC	cmol (p ⁺) kg ⁻¹	>20	10-20	10-5.0	<5.0
Rooting conditions	Effective soil depth	cm	>100	100-75	75-50	<50
	Stoniness	%	<15	15-35	35-50	>50
Soil toxicity	Salinity (ECe)	dS m ⁻¹	<2.0	2.0-4.0	4.0-9.0	>9.0
	Sodicity (ESP)	%	<10	10-15	15-25	>25
Erosion hazard	Slope	%	<3	3-5	5-8	>8
Note: s- sand; ls- loamy sand; sl- sandy loam; scl- sandy clay loam; cl- clay loam; sil- silt loam; l- loam; sic- silty clay; sc-sandy clay; c- clay, Clay (m/k)= mixed /kaolinitic; Clay (ss)= shrink-swell clays, Source: Naidu (1999)						

3.2.10 Statistical analysis

The simple correlations among different parameters were worked out following standard method given by Panse and Sukhatme, (1967) and results were discussed accordingly.

RESULTS AND DISCUSSION



IV. RESULTS AND DISCUSSION

The present investigation entitled “Soil fertility status of paddy and sugarcane growing areas of village Butlaw and Dabhalia of Navsari district” was carried out by collecting surface (0 to 20 cm) and sub-surface (20 to 40 cm) samples from hundred and two locations based on grid points with the help of GPS and horizon wise profile samples of representing soils of the area. The samples were analyzed for physical and chemical properties of soils as well as for available nutrients. Simultaneously ground water samples were collected and analyzed. The secondary data for climatic parameters were collected from the respective department and analyzed accordingly. The results obtained during present study are presented and discussed under the following major heads.

4.1: Soil

4.1.1 Profile soil

4.1.1.1: Soil classification

In order to understand the soils of the study area properly, total three profiles were excavated considering the land forms delineated while traversing the area. Based on the horizon wise physical and chemical properties of the soils, taxonomic classification was done by adopting the standard procedure as described in revised edition of Soil Survey Manual (Soil Survey Staff 2006). The detail description of each profile and its classification is given here along with landform photo. Similarly, the physical and chemical properties along with fertility status of each profile is also been discussed here.

Vertisols: The soils of profile 1 and 2 are placed under order vertisols as they have

- I) A layer 25 cm or thick, with an upper boundary within 100 cm of the mineral soil surface, that has either slicken sides or wedge shaped peds that have their long tilted to 10 to 60° from the horizontal.
- II) The presence of smectite minerals they have more than 30 per cent clay in all horizon.
- III) More than 5 mm cracks that remain open and close periodically during summer and winter months and remains closed for 1 to 2 during rainy season (Soil Survey Staff, 1998).

The presence of smectite mineralogy, hyperthermic soil temperature regime, ustic soil moisture regime and less than 60 per cent of clay content in control section, profile 1 is classified as fine, smectitic, Hyperthermic Typic Haplusterts at family levels. While in the case of profile 2 more than 60 per cent of clay content in control section, profile 2 is classified as very fine, smectitic, Hyperthermic Typic Haplusterts at family levels.

Inceptisols: The soil of profile 3 is placed in order Inceptisols owing to ochric epipedon followed by cambic horizon (changes in colour, structure and texture). The moisture regime for the region is Ustic so the suborder is ustepts. At great group levels the profile is classified as Haplustepts and Fine, Mixed, Hyperthermic Typic Haplustepts at family levels.

Plate I: Land form and profile pit No. 1

Location	Village: Butlaw; Taluka: Navsari; District: Navsari; Latitude: 20°54'30.47"N; Longitude: 73°04'24.24"E; Altitude : 96 feet; Slope: 0 to 1 per cent
Taxonomic classification	Order: Vertisols; Sub-Order: Usterts; Great Group: Haplusterts; Sub-Group: Typic Haplusterts; Family: Very Fine, Smectitic, Hyperthermic Typic Haplusterts

Profile # PN 1: Horizon wise description of the profile

Horizon	Depth (cm)	Description
Ap	0-25	Very dark grayish brown (10YR3/2 moist) and dark brown (10YR3/3 dry); moderate coarse crumby structure; clay texture; Dry-hard, moist-friable and wet-slightly sticky consistence; fine roots plentiful, no concretion, diffuse boundary, slight effervescence; moderate to well drainage.
B21	25-50	Dark brown (10YR4/3 moist and dry); moderate coarse platy structure; clay texture; Dry-hard, moist-friable and wet-sticky consistence; fine roots few; no concretion; diffuse boundary; slight effervescence; moderate to well drainage.
B22ss	50-75	Very dark grayish brown (10YR3/2 moist & dry); strong coarse platy structure; clay texture; Dry-hard, moist-friable and wet-sticky consistence; fine roots few; diffuse boundary; slight effervescence; moderate drainage.
B23ss	75-105	Very dark grayish brown (10YR3/2 moist) and dark brown (10YR3/3 dry); strong coarse structure; clay texture; Dry-semi hard, moist-friable and wet-slightly plastics consistence; no concretion; diffuse boundary, slight effervescence; moderate drainage.
B24ss	105+	Very dark grayish brown (10YR3/2 moist) and dark brown (10YR3/3 dry); strong coarse structure; clay texture; Dry-semi hard, moist-friable and wet-slightly plastics consistence; no concretion; diffuse boundary; slight effervescence; moderate drainage.

Plate II: Land form and profile pit No. 2



Location	Village: Dabhalia; Taluka: Navsari; District: Navsari; Latitude: 20°54'43.96"N; Longitude: 73°04'44.239"E; Altitude: 100 feet; Slope: 0 to 1 per cent
Taxonomic classification	Order: Vertisols; Sub-Order: Usterts; Great Group: Haplusterts; Sub-Group: Typic Haplusterts; Family: Very Fine, Smectitic, Hyperthermic Typic Haplusterts

Profile # PN 2: Horizon wise description of the profile

Horizon	Depth (cm)	Description
Ap	0-30	Very dark grayish brown (10YR3/2 moist) and dark brown (10YR3/3 dry); moderate very fine platy structure; clay texture; Dry-hard, moist-firm sticky and wet-plastic consistence; fine roots plentiful; no concretion; diffuse boundary; slight effervescence; moderate to well drainage.
B21ss	30-60	Dark brown (10YR4/3 moist and dry); moderate very fine platy structure; clay texture; Dry-hard, moist-firm sticky and wet-plastic consistence; fine roots few; no concretion; diffuse boundary; slight effervescence; moderate drainage.
B22ss	60-85	Dark brown (10YR4/3 moist and dry); moderate very fine platy structure; clay texture; Dry-semi hard, moist-firm sticky and wet-plastic consistence; no roots, no concretion, diffuse boundary; slight effervescence; moderate drainage.
B23ss	85-110	Dark yellowish brown (10YR4/4 moist) and yellowish brown (10YR5/4 dry); moderate very fine platy structure; clay texture; Dry-semi hard, moist-firm sticky and wet-plastic consistence; no roots; no concretion; diffuse boundary; slight effervescence; moderate drainage.

Plate III: Land form and profile pit No. 3



Location	Village: Butlaw; Taluka: Navsari; District: Navsari; Latitude: 20°54'26.38"N; Longitude: 73°05'17.54"E; Altitude : 105 feet; Slope: 0 to 1 per cent
Taxonomic classification	Order: Inceptisols; Sub-Order: Ustepts; Great Group: Haplustepts; Sub-Group: Typic Haplustepts; Family: Fine, Mixed, Hyperthermic Typic Haplustepts

Profile # PN 3: Horizon wise description of the profile

Horizons	Depth (cm)	Description
Ap	0-25	Very dark grayish brown (10YR3/2 moist and dry); subangular blocky structure; dry-very hard, moist-friable and wet-slightly sticky consistence; medium common pores, medium fine roots, clear and smooth boundary, slight effervescence; moderate to well drainage.
B21	25-50	Very dark grayish brown (10YR3/2 moist and dry); subangular blocky structure; dry-hard, moist-friable and wet-slightly sticky consistence; medium common pores; medium fine root; clear and smooth boundary; slight effervescence; moderate to well drainage.
B22	50-70	Dark brown (10YR4/3 moist and dry); subangular blocky structure; dry-hard, moist-friable and wet-slightly sticky consistence; very fine medium pores, few very fine roots, clear and smooth boundary, slight effervescence.
C1	70-90	Dark yellowish brown (10YR4/4 moist) and yellowish brown (10YR5/4 dry); massive structure; dry-hard, moist-friable and wet-slightly plastic, very fine medium pores, clear and smooth boundary; few concretion of calcium carbonate; slight effervescence.
C2	90-110	Dark yellowish brown (10YR4/4 moist) and yellowish brown (10YR5/4 dry); massive structure; dry-slightly hard, moist-friable and wet-slightly plastic consistence, medium common pores, few concretion of calcium carbonate, clear and smooth boundary, moderate effervescence.

4.1.1.2 Physical properties of profile soils

The horizon wise physical properties of profile samples along with range and mean values are presented here (Table 4.1). The depth of profiles was found more than 110 cm. So, all the areas representing different profiles are deep from depth point of view. Among the mechanical separates, proportion of sand was ranging from minimum of 8.84 per cent in profile No. 2 to maximum of 34.56 per cent in profile No. 3 with an overall mean of 18.58 per cent. The silt content was ranging from 18.40 per cent in profile No. 3 to as high as 32.52 per cent in profile No. 1 with an overall mean of 23.72 per cent. Clay content is ranging from 45.27 per cent in profile No. 3 to maximum 69.45 per cent in profile No. 2 with an overall mean of 57.70 per cent. This clearly implies that clay content in the profiles of study area dominant and hence, the textural class of the profile samples is clay. The bulk density showed considerable variations with profile and depth. In the case of profile No. 1 and 3 there is increase in bulk density with the depth but there was no consistency with depth in the case of profile No. 2. The bulk density of different layers of the profiles were ranged from 1.32 Mg m^{-3} in the profile No. 2 to 1.51 Mg m^{-3} in the profile No. 1 with mean of 1.43 Mg m^{-3} . The particle density of different horizons soils ranging from 2.55 Mg m^{-3} in the profile No. 3 to 2.63 Mg m^{-3} in the profile No. 1 with an overall mean of 2.60 Mg m^{-3} . The porosity is ranging from 42.15 per cent in the profile No. 1 to 49.61 per cent in the profile No. 2 with overall mean of 45.38 per cent. The overall water stable aggregate of more than 1 mm size was 14.55 per cent and between 0.5 to 1.0 mm size was 23.59 per cent. From the moisture content at 1/3 and 15 bar, available moisture was computed which is varying between 7.58 per cent in the profile No. 3 to 14.94 per cent

Table 4.1: Physical properties of profile soils

PN	Depth (cm)	Content (%)			Texture	BD (Mg m ⁻³)	PD (Mg m ⁻³)	Porosity (%)	WSA (%)		Moisture (%)		
		Sand	Silt	Clay					>1 (mm)	0.5 -1.0 (mm)	1/3bar	15bar	AWC
1	0-25	10.32	32.52	57.16	c	1.44	2.61	44.83	12.56	20.12	31.15	23.19	7.96
	25-50	16.29	31.26	52.45	c	1.46	2.59	43.63	14.45	22.47	33.33	24.76	8.58
	50-75	18.42	28.52	53.06	c	1.47	2.62	43.89	22.36	21.45	35.14	23.84	11.30
	75- ¹ 05	19.88	24.96	55.16	c	1.51	2.63	42.59	12.46	22.43	34.38	22.13	12.25
	>105	17.82	25.34	56.84	c	1.51	2.61	42.15	12.43	23.58	36.36	21.43	14.94
	Min	10.32	24.96	52.45		1.44	2.59	42.15	12.43	20.12	31.15	21.43	7.96
	Max	19.88	32.52	57.16		1.51	2.63	44.83	22.36	23.58	36.36	24.76	14.94
	Mean	16.55	28.52	54.94		1.48	2.61	43.42	14.85	22.01	34.07	23.07	11.00
2	0-21	14.59	20.27	65.14	c	1.32	2.62	49.61	13.18	23.84	35.36	23.89	11.47
	21-56	11.4	24.56	64.04	c	1.36	2.61	47.89	18.34	24.86	33.43	21.15	12.28
	56-80	10.63	20.42	68.95	c	1.41	2.63	46.38	15.32	22.24	34.93	23.61	11.32
	80- ¹ 00	8.84	21.71	69.45	c	1.37	2.61	47.50	12.7	29.62	36.06	23.19	12.87
	Min	8.84	20.27	64.04		1.32	2.61	46.38	12.70	22.24	33.43	21.15	11.32
	Max	14.59	24.56	69.45		1.41	2.63	49.61	18.34	29.62	36.06	23.89	12.87
	Mean	11.37	21.73	66.90		1.37	2.62	47.85	14.89	25.14	34.95	22.96	11.99
3	0-25	26.23	18.4	55.37	c	1.37	2.56	46.48	27.82	15.72	34.13	23.35	10.78
	25-50	24.62	21.82	53.56	c	1.38	2.55	45.88	15.84	22.66	33.73	22.35	11.38
	50-70	24.50	23.66	51.84	c	1.43	2.60	45.00	10.98	27.98	32.66	21.76	10.90
	70-90	29.22	20.5	50.28	c	1.45	2.59	44.01	10.64	20.18	30.14	22.56	7.58
	90- ¹ 10	34.56	20.17	45.27	c	1.49	2.61	42.91	7.16	22.50	32.89	23.77	9.12
	Min	24.50	18.4	45.27		1.37	2.55	42.91	7.16	15.72	30.14	21.76	7.58
	Max	34.56	23.66	55.37		1.49	2.61	46.48	27.82	32.66	34.13	23.77	11.38
	Mean	27.83	20.91	51.26		1.43	2.582	44.86	13.92	23.62	32.71	22.76	9.95
Overall	Min	8.84	18.4	45.27		1.32	2.55	42.15	7.16	15.72	30.14	21.15	7.58
	Max	34.56	32.52	69.45		1.51	2.63	49.61	27.82	32.66	36.36	24.76	14.94
	Mean	18.58	23.72	57.70		1.43	2.60	45.38	14.55	23.59	33.91	22.93	10.98
BD = Bulk density, PD = Particle density, WSA= Water stable aggregates, AWC= Available water holding capacity, c = Clay													

in profile No. 1 with an overall mean of 10.98 per cent. Though, the moisture content is high in all the profiles, yet the available moisture is relatively low because of heavy texture of the soils.

4.1.1.3 Chemical properties of profile soils

The values of chemical properties *viz.* $\text{pH}_{(1:2.5)}$, ECe, ESP, CEC and CaCO_3 are presented here (Table 4.2). Irrespective of the profiles and different horizons the $\text{pH}_{(1:2.5)}$ values is ranging from 7.62 to 8.75 in the profile No.1 and profile No. 2, respectively with a mean of 8.18. It shows that soils of the study area are alkaline in reaction. The ECe values are ranging from minimum of 0.51 dSm^{-1} in the profile No. 3 to 2.29 dSm^{-1} profile No. 2 with a mean of 1.02 dSm^{-1} . In the context of textural class of the soils, these soils does not have salinity problem. The CEC values are ranging from 38.90 to $46.77 \text{ cmol(p}^+)\text{kg}^{-1}$ soil in the profile No. 3 and profile No. 2, respectively with a mean of $44.58 \text{ cmol(p}^+)\text{kg}^{-1}$. In general, these soils are having good retentions capacity *i.e.*, well nutrient supply capacity as well as water holding capacity. The mean CEC of individual profile differed slightly from each other. However, the magnitude of CEC changes with depth following irregular pattern, which might be due to presence of varying proportions of sand, silt, clay, and exchangeable Na^+ , Ca^{2+} and Mg^{2+} ions. From sodicity point of view, the ESP value ranging from 0.93 to 5.47 per cent in the profile No.1 and profile No. 2, respectively with a mean of 2.78 per cent. The soils do not have any sodicity problem. There is a presence of free lime (CaCO_3 equivalent) in all the profiles and at all the depths the minimum and maximum values are 0.61 per cent and 1.68 per cent in the profile No. 3 and profile No. 2, respectively with a mean of 0.92 per cent. However, the soils are non calcareous in nature.

Table 4.2: Chemical properties of profile soils

Profile No.	Depth (cm)	pH _(1:2.5)	ECe (dS m ⁻¹)	CEC (cmol(p ⁺)kg ⁻¹)	ESP %	CaCO ₃ (%)
PN 1 Butlaw (Typic Haplusterts)						
P1/1	0-25	7.62	0.65	44.18	0.93	0.68
P1/2	25-50	7.95	0.72	46.02	1.41	0.76
P1/3	50-75	8.16	0.79	47.87	1.86	0.83
P1/4	75-110	8.46	0.85	44.28	3.18	0.93
P1/5	>105	8.54	0.85	42.78	2.66	0.99
	Min	7.62	0.65	42.78	0.93	0.68
	Max	8.54	0.85	47.87	3.18	0.99
	Mean	8.15	0.79	45.03	2.01	0.84
PN 2 Dabhalia (Typic Haplusterts)						
P3/1	0-30	7.99	1.27	45.45	3.50	0.66
P3/2	30-60	8.30	1.33	46.55	4.21	0.97
P3/3	60-85	8.49	1.61	43.85	4.83	1.33
P3/4	85-110	8.75	2.29	46.77	5.47	1.68
	Min	7.99	1.27	43.85	3.50	0.66
	Max	8.75	2.29	46.77	5.47	1.68
	Mean	8.38	1.63	45.66	4.50	1.16
PN 3 Butlaw (Typic Haplusterts)						
P2/1	0-25	7.98	0.79	44.65	1.75	0.61
P2/2	25-50	8.13	0.82	45.93	1.79	0.73
P2/3	50-70	8.21	0.61	44.90	1.85	0.88
P2/4	70-90	7.85	0.51	40.87	1.86	0.65
P2/5	90-110	7.91	0.51	38.90	1.95	0.97
	Min	7.85	0.51	38.90	1.75	0.61
	Max	8.21	0.82	45.93	1.95	0.97
	Mean	8.01	0.65	43.05	1.84	0.77
Overall	Min	7.62	0.51	38.9	0.93	0.61
	Max	8.75	2.29	47.87	5.47	1.68
	Mean	8.18	1.02	44.58	2.78	0.92

4.1.1.4 Fertility status of profile soils

For assessing the soil fertility, the parameters *viz.* organic carbon, available N, P_2O_5 , K_2O , S and available micronutrient cations (Fe, Mn, Cu, Zn) were determined and the data are reported in table 4.3. The most important parameter from fertility point of view is organic carbon content which is ranging from 0.15 per cent to 1.83 per cent with a mean value of 0.66 per cent following decreasing trend with increase in the soil depth in all the profile. This was also true for all the available nutrients. From available N, P_2O_5 , K_2O and S content point of view, the mean values suggest low, medium, medium and high status, respectively. However, the mean values of available micronutrient cations are indicating Fe content is high, Mn content is medium, Zn content is low and Cu content is high. Of course, depth and profile wise variation do exist in the study area, overall decrease in nutrient content with the increase in soil depth may be due to lower mineralization and less organic matter content in sub-surface layers. The sharp difference of available phosphorus in the surface and sub-surface region might be due to the excess phosphatic fertilizer use which might be accumulated in soil. Rich soil organic carbon content of the surface layer of profile soil may also contribute to the higher phosphorus availability in the surface layer. Available nitrogen and zinc content is main concern in this study area because their content is relatively low in the soil. So, there is a need for better nitrogen and zinc management to make the soil more fertile, productive and sustainable.

Table 4.3: Fertility status of profile soils

Profile No.	Depth (cm)	O.C. (%)	Available nutrients (kg ha ⁻¹)			Available nutrients (mg kg ⁻¹)				
			N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Zn	Cu
	PN 1 Butlaw (Typic Haplusterts)									
P1/1	0-25	1.41	122	113	240	21	21.13	24.39	0.97	4.75
P1/2	25-50	0.71	61	9	218	14	7.28	13.29	0.41	2.89
P1/3	50-75	0.63	61	10	204	13	6.02	12.52	0.44	3.36
P1/4	75-105	0.54	41	8	196	13	3.51	8.77	0.45	2.61
P1/5	>105	0.42	41	6	191	12	4.77	8.90	0.43	4.38
	Min	0.42	41	6	191	12	3.51	8.77	0.41	2.61
	Max	1.41	122	113	240	21	21.13	24.39	0.97	4.75
	Mean	0.74	65	29	210	15	8.54	13.57	0.54	3.60
	PN 2 Dabhalia (Typic Haplusterts)									
P3/1	0-30	1.53	143	152	218	197	65.19	14.19	0.99	7.36
P3/2	30-60	0.51	51	17	190	110	11.69	6.45	0.24	2.61
P3/3	60-85	0.51	41	13	157	123	16.1	8.72	0.52	3.54
P3/4	85-110	0.18	21	4	148	101	6.02	7.35	0.28	1.03
	Min	0.18	21	4	148	101	6.02	6.45	0.24	1.03
	Max	1.83	143	152	218	197	65.19	14.19	0.99	7.36
	Mean	0.76	64	47	178	133	24.75	9.18	0.51	3.64
	PN 1 Butlaw (Typic Haplustepts)									
P2/1	0-25	1.08	118	76	259	23	31.20	9.68	0.55	5.96
P2/2	25-50	0.54	51	13	231	15	7.28	4.64	0.47	3.12
P2/3	50-70	0.36	41	10	196	19	9.01	3.61	0.41	2.31
P2/4	70-90	0.24	31	8	149	19	5.61	5.55	0.31	0.93
P2/5	90-110	0.15	20	7.	134	16	7.63	4.26	0.41	0.84
	Min	0.15	20	7	134	14	5.61	3.61	0.31	0.84
	Max	1.08	118	76	259	23.	31.20	9.68	0.55	5.96
	Mean	0.48	52	23	194	18	12.15	5.55	0.43	2.63
Overall	Min	0.15	20	4	134	12	3.51	3.61	0.24	0.84
	Max	1.83	143	152	190	197	65.19	24.39	0.99	7.36
	Mean	0.66	60	32	193	55	15.15	9.43	0.49	3.29

4.1.2 Surface and sub-surface soil properties

Apart from profile samples, 102 each of surface (0-20 cm) and sub-surface (20-40 cm) soil samples were also collected from the representative area of each profile based on grouping of adjoining survey numbers fields of approximately same topographic situation and land use. The chemical and fertility related properties of these soil samples are described here.

4.1.2.1 Chemical properties

Under this caption, the soil properties *viz.* pH, EC, ESP and CEC are presented here depth wise. The pH value is ranging from 6.74 in the area of profile No. 3 (Eastern part of Butlaw and Dabhalia village) to 8.18 in the area of profile No. 1 (Western part of Butlaw village) with an overall mean of 7.38 in the case of surface soils (Table 4.4). The corresponding values of pH are 7.13 in the area of profile No. 2 (Western part of Dabhalia) and 8.70 in the area of profile No. 1 for the sub-surface samples with an overall mean of 7.87. In general pH value tended to increase with depth of sampling. The increase in soil reaction might be due to the presence of more amounts of Na^+ Ca^{2+} Mg^{2+} in the sub-surface layer. From distribution point of view, on overall basis, about 76.47 per cent surface samples and 17.65 per cent sub-surface samples were categorized in normal groups (pH 6.5 to 7.5). In general, the soils are neutral to slightly alkaline in reaction.

With regards to surface soil salinity, the minimum EC value of 0.06 dS m^{-1} is recorded in the area of profile No. 3 and that of maximum value of 0.53 dS m^{-1} is recorded in the area of profile No. 2 (Table 4.5). In the case of sub-surface soils the minimum EC value of 0.07 dS m^{-1} recorded in the area of profile No. 3 and that of

maximum value of 0.47 dS m^{-1} is in the area of profile No. 2. The overall mean values for the surface soils 0.19 and 0.15 dS m^{-1} for the sub-surface soils *i.e.*, less than 1.0 dS m^{-1} , suggest that the 100 per cent soil samples are non-saline in nature. However, in the study area farmers are growing high water consuming crops viz., summer paddy and sugarcane should have proper agricultural drainage system, as the soils are clay in nature salinity may developed in due course of time. Further, in the area of profile No. 2 where mean soil EC value recorded is 1.63 dS m^{-1} also have critical water table level (less than 2.0 m) and that too after two months of canal closer period suggest the covered under profile No.2 required drainage systems.

The overall CEC of surface and sub-surface soils layers are between 33.75 to $51.66 \text{ cmol(p}^+)\text{kg}^{-1}$ and 39.13 to $61.20 \text{ cmol(p}^+)\text{kg}^{-1}$, respectively with the mean of 42.02 and $48.68 \text{ cmol (p}^+)\text{kg}^{-1}$. However, about 60.64 per cent surface as well as 58.85 per cent sub-surface samples have 40 to $50 \text{ cmol(p}^+)\text{kg}^{-1}$ CEC. This suggests that the soils of the study area are clay in texture (Table 4.6).

Minimum ESP value of 0.62 per cent is registered in the area of profile No. 3 and that of maximum value of 6.45 per cent in the area of profile No. 1 with an overall mean of 1.66 per cent. This clearly indicates that there is no sodicity problem in the soils. This was also reflected on the classification *i.e.*, more than 99 per cent surface as well as sub-surface samples are in non sodic group and rest in slightly sodic group (Tables 4.7).

Table 4.4: Range and mean $\text{pH}_{(1:2.5)}$ values of surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	N	SA	MA	Range	Mean	N	SA	MA
1	28	6.98-8.18	7.49	60.71	39.29	0.0	7.59-8.70	8.13	0	89.29	10.71
2	27	7.01-8.10	7.36	70.37	29.63	0.0	7.13-8.56	7.80	25.93	70.37	3.70
3	47	6.74-7.85	7.29	89.36	10.64	0.0	7.27-8.31	7.68	23.40	76.60	0.0
Overall	102	6.74-8.18	7.38	76.47	23.53	0.0	7.13-8.70	7.87	17.65	78.43	3.92
N= Normal (pH 6.5-7.5) SA= Slightly alkaline (pH 7.5 to 8.5), MA=Moderately alkaline (pH 8.5 to 9.5)											

Table 4.5: Range and mean $\text{EC}_{(1:2.5)}$ (dS m^{-1}) values of surface and sub-surface soil samples and their distribution into different salinity classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	NS	SS	MS	Range	Mean	N	SS	MS
1	28	0.13-0.46	0.20	100	0.0	0.0	0.11-0.27	0.16	100	0.0	0.0
2	27	0.12-0.53	0.19	100	0.0	0.0	0.09-0.41	0.15	100	0.0	0.0
3	47	0.06-0.47	0.18	100	0.0	0.0	0.07-0.25	0.13	100	0.0	0.0
Overall	102	0.06-0.53	0.19	100	0.0	0.0	0.07-0.41	0.15	100	0.0	0.0
NS= Non saline ($<1 \text{ dS m}^{-1}$), SS= Slightly saline ($1-2 \text{ dS m}^{-1}$), MS= Moderately saline ($2-3 \text{ dS m}^{-1}$)											

Table 4.6: Range and mean CEC values of surface and sub-surface soil samples and their Categorization into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	30-40	40-50	>50	Range	Mean	30-40	40-50	>50
1	28	33.75-47.58	39.20	60.71	39.29	0.0	39.13-56.86	46.52	3.57	71.43	25.0
2	27	36.56-51.66	45.03	7.40	85.20	7.40	43.57-61.20	51.30	0.0	37.04	62.96
3	47	35.08-50.69	41.82	38.30	57.44	4.26	42.15-57.02	48.23	0.0	68.09	31.91
Overall	102	33.75-51.66	42.02	35.47	60.64	3.89	39.13-61.20	48.68	1.19	58.85	39.96

Table 4.7: Range and mean ESP values of surface and sub-surface soil samples and their distribution in to different sodicity classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	NS	SS	MS	Range	Mean	NS	SS	MS
1	28	0.80-6.45	1.88	96.43	3.57	0	1.05-7.37	2.11	96.43	3.57	0
2	27	1.11-4.20	1.80	100	0	0	0.99-4.64	1.84	100	0	0
3	47	0.62-2.09	1.31	100	0	0	0.86-2.87	1.39	100	0	0
Overall	102	0.62-6.45	1.66	99.02	0.98	0	0.86-7.37	1.78	99.02	0.98	0
NS= Non sodic (<5), SS= Slightly sodic (5-15), MS= Moderately sodic (15-30)											

4.1.2.2 Fertility status

For assessing the fertility status of the soil, surface and sub-surface samples were collected from the adjoining areas of each profile. These samples were categorized in to low, medium and high groups using the standard values (Perur *et al.*, 1973). In the case of organic carbon status (Table 4.8), highest organic carbon content in the surface soils was found in the area of profile No. 1 followed by the area of profile No. 3 and 2 but in the case of sub-surface soils highest organic carbon was found in the area of profile No. 3 followed by the area of profile No. 1 and 2. On overall basis, no surface soil samples was recorded as low, the per cent samples in medium and high were 8.74 and 91.26 per cent, respectively. Whereas, in the case of sub-surface samples also higher percentage of samples were grouped in high OC content (70.19 per cent) followed by medium (22.49 per cent) and least in low group (7.32 per cent). The reasons behind high organic carbon content in soils of the area are most of the farmers practice green manuring, apply organic residues, cultivates spider lili and excess irrigation in the fields which causes an anaerobic condition and resulted less decomposition of organic matter.

The available N content in surface soils was ranging from 173 kg ha⁻¹ in the area of profile No. 1 to 326 kg ha⁻¹ in both the area of profile No. 1 and 2, with an overall mean of 246 kg ha⁻¹. The available N content in sub-surface soils was ranging from 71 kg ha⁻¹ in the area of profile No. 1 and 2 to 204 kg ha⁻¹ in both the area of profile No. 2 and 3, with an overall mean of 157 kg ha⁻¹. Irrespective of profile, the surface samples were almost equally distributed in low (54.16 per cent) and medium available N (45.84

per cent) categories only. While in the case of sub-surface samples, 100 per cent samples were categorized in to low category only (Table 4.9). The reason behind low available nitrogen content might be the intensive agricultural, where high yielding varieties of paddy and sugarcane crops are grown, which have very high nutrients requirements.

The available P_2O_5 content in surface soils was ranging from 39 kg ha⁻¹ in the area of profile No. 2 and 3 to 329 kg ha⁻¹ in the area of profile No. 1 with an overall mean of 169 kg ha⁻¹. The available P_2O_5 content in sub-surface samples was ranging from 24 to 267 kg ha⁻¹ in the area of profile No. 3, with an overall mean of 116 kg ha⁻¹. Irrespective of profile, 94.88 per cent surface samples were high in available P_2O_5 content while remaining 5.12 per cent are medium. In the case of sub-surface samples 92.75 per cent surface samples were high in available P_2O_5 content while remaining 7.25 per cent are medium (Table 4.10). The reason behind high available phosphorus content in the soils might be due to excessive use of phosphatic fertilizers and high organic matter content in the soil.

The available K_2O content in surface soils was ranging from 202 to 875 kg ha⁻¹ with an overall mean of 345 kg ha⁻¹. The available K_2O content in sub-surface samples was ranging from 149 to 664 kg ha⁻¹ an overall mean of 271 kg ha⁻¹. Irrespective of profile groups, 64.59 per cent surface samples were high in available K_2O content while remaining 35.41per cent are medium. In the case of sub-surface samples 31.94 per cent surface samples were high in available K_2O content while remaining 68.06 per cent are medium (Table 4.11).

The available S content in surface samples was ranging from 12.16 to 120.06 mg kg⁻¹ with an overall mean of 35.57 mg kg⁻¹. The available S content in sub-surface samples was ranging from 8.89 to 108.84 mg kg⁻¹ with an overall mean of 26.01 mg kg⁻¹. Irrespective of profile, 81.98 per cent surface samples were high in available S content while remaining 18.02 per cent are medium. In the case of sub-surface samples 57.54, 35.39 and 7.07 per cent surface samples were high, medium and low in available S content, respectively (Table 4.12).

So, from the major nutrients point of view farmer have to be more careful about nutrient management practices. Although, the soils are rich the organic carbon content the available nitrogen content is low and the reason behind might be the excess irrigation throughout the growing season causes unfavorable condition for mineralization of nutrients. Nitrogen management should be done following the soil test values along with proper agronomic practices. Soils are high in available phosphorus, so general RDF must be changed and soil test values should be followed for phosphatic fertilizer application. By nature the soils of south Gujarat is high in available potassium, so wherever the content is high, the RDF must be reviewed based on the soil test values. Adequate amount of sulphur is present in the study area as 82 per cent surface soil samples are high in available sulphur. So, there is no need for application of any source of sulphur only application of organic matter is sufficient.

Table 4.8: Range and mean of organic carbon content (%) in surface and sub-surface soil samples and their distribution in to different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	L	M	H	Range	Mean	L	M	H
1	28	0.63-1.65	1.24	0.0	7.14	92.86	0.43-1.27	0.84	7.14	25	67.86
2	27	0.58-1.69	1.01	0.0	14.81	85.19	0.44-1.07	0.82	14.81	14.81	70.38
3	47	0.69-1.87	1.09	0.0	4.26	95.74	0.54-1.59	0.86	0.0	27.66	72.34
Overall	102	0.58-1.87	1.11	0.0	8.74	91.26	0.43-1.59	0.81	7.32	22.49	70.19
L= Low (< 0.50 %), M= Medium (0.50-0.75 %) and H= High (>0.75%)											

Table 4.9: Range and mean of available N (kg ha⁻¹) content in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	L	M	H	Range	Mean	L	M	H
1	28	194-326	276	21.43	78.57	0.0	71-163	120	100	0.0	0.0
2	27	194-296	223	81.48	18.52	0.0	71-204	148	100	0.0	0.0
3	47	173-326	239	59.57	40.43	0.0	92-204	145	100	0.0	0.0
Overall	102	173-326	246	54.16	45.84	0.0	71-204	157	100	0.0	0.0
L= Low (<250 kg ha⁻¹), M= Medium (250-500 kg ha⁻¹) and H= High (>500 kg ha⁻¹)											

Table 4.10: Range and mean of available P_2O_5 content ($kg\ ha^{-1}$) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	L	M	H	Range	Mean	L	M	H
1	28	81-329	181	0.0	0.0	100	59-213	123	0.0	0.0	100
2	27	39-291	159	0.0	11.11	88.89	29-259	108	0.0	11.11	88.89
3	47	39-325	168	0.0	4.26	95.74	24-267	118	0.0	10.64	89.36
Overall	102	39-329	169	0.0	5.12	94.88	24-267	116	0.0	7.25	92.75
L= Low ($<22.9\ kg\ ha^{-1}$), M= Medium ($22.9-57.25\ kg\ ha^{-1}$) and H= High ($>57.25\ kg\ ha^{-1}$)											

Table 4.11: Range and mean of available K_2O content ($kg\ ha^{-1}$) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	L	M	H	Range	Mean	L	M	H
1	28	206-786	349	0.0	35.71	64.29	149-530	263	0.0	67.86	32.14
2	27	222-642	325	0.0	40.74	59.26	199-379	266	0.0	70.37	29.63
3	47	202-875	361	0.0	29.79	70.21	190-664	283	0.0	65.96	34.04
Overall	102	202-875	345	0.0	35.41	64.59	149-664	271	0.0	68.06	31.94
L= Low ($<140\ kg\ ha^{-1}$), M= Medium ($140-280\ kg\ ha^{-1}$) and H= High ($>280\ kg\ ha^{-1}$)											

Table 4.12: Range and mean of available S content (mg kg^{-1}) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	L	M	H	Range	Mean	L	M	H
1	28	20.59-64.10	36.09	0.0	0.0	100	10.76-47.72	25.35	0.0	25	75
2	27	12.63-120.06	34.65	0.0	37.04	62.96	8.89-108.84	26.32	14.82	40.74	44.44
3	47	12.16-88.49	35.98	0.0	17.02	82.98	8.89-73.92	26.36	6.38	40.43	53.19
Overall	102	12.16-120.06	35.57	0.0	18.02	81.98	8.89-108.84	26.01	7.07	35.39	57.54
L= Low ($<10 \text{ mg kg}^{-1}$), M= Medium ($10\text{-}20 \text{ mg kg}^{-1}$) and H= High ($>20 \text{ mg kg}^{-1}$)											

Among the micronutrients, only DTPA extractable cations *viz.* Fe, Mn, Zn and Cu were determined. The available Fe content of surface soils was ranging from 15.43 mg kg⁻¹ in the area of profile No. 1 to 127.70 mg kg⁻¹ in the area of profile No. 3 with an overall mean of 52.36 mg kg⁻¹. In the case of sub-surface soil, available Fe content was ranging from 11.37 mg kg⁻¹ in the area of profile No. 1 to 110.80 mg kg⁻¹ in the area of profile No. 3 with an overall mean of 43.21 mg kg⁻¹ (Table 4.13). From distribution point of view, 100 per cent surface and sub-surface samples were classified under sufficient class. This result shows the adequacy of iron in the soil.

The available Mn content of surface soils was ranging from 16.77 mg kg⁻¹ in the area of profile No. 2 to 46.32 mg kg⁻¹ in the area of profile No. 3 with an overall mean of 31.14 mg kg⁻¹. For sub-surface soil, these values were 12.13 mg kg⁻¹ to 36.23 mg kg⁻¹ in the areas of profile No. 3 with an overall mean of 22.17 mg kg⁻¹ (Table 4.14). From distribution point of view, all the surface and sub-surface samples were classified under sufficient class. This result indicates that the soils of the study area are having very rich source of Mn in the soil.

The available Cu content in surface layer was ranging from 5.00 mg kg⁻¹ to 16.36 mg kg⁻¹ in the area of profile No. 3 with an overall mean of 8.24 mg kg⁻¹. For sub-surface soil, these values were 2.45 mg kg⁻¹ in the area of profile No.2 to 14.63 mg kg⁻¹ in the area of profile No.3 with an overall mean of 5.83 mg kg⁻¹ (Table 4.15). From distribution point of view, 100 per cent surface as well as sub-surface samples were also classified under sufficient class. The reason behind this result might be the high organic carbon content of the soil and soil mineralogy.

The available Zn content in surface layer was ranging from 0.50 mg kg⁻¹ in the area of profile No. 3 to 2.74 mg kg⁻¹ in the area of profile No. 2, with an overall mean of 1.20 mg kg⁻¹. For sub-surface soil, these values were 0.36 mg kg⁻¹ in the area of profile No. 3 to 2.24 mg kg⁻¹ in the area of profile No. 2, with an overall mean of 0.90 mg kg⁻¹ (Table 4.16). From distribution point of view, of the surface soils 63.85 per cent samples were in sufficient category and remaining 36.15 per cent were in marginal category. In the case of sub-surface samples 61.25 per cent were in marginal category followed by 24.61 per cent in sufficient category and 14.14 per cent in deficient category. So, from this result it is found that management of zinc is one of the most important concerns in the study area.

4.1.2.3 Nutrient Index

The purpose of soil analysis is to assess the adequacy, surplus or deficiency of available nutrients for optimum crop production, to avoid transferring undesirable levels of some nutrients into the environment and to ensure a suitable nutrient content in crop products. To aid interpretation of the different concentrations of individual nutrients, Index or descriptive scales are used. These scales provide a general indication of the likely crop response as shown here (Table 4.17). Organic carbon, available phosphorus, potassium, iron, manganese and copper are showing high nutrient index in the all profile areas in both the surface and sub-surface layers, which ensures high fertility level of the respective soils.

Available nitrogen is showing medium, low and high nutrient index in the surface soils of the profile area 1, 2 and 3 respectively. In the case of sub-surface soils the corresponding values are low in

Table 4.13: Range and mean of available Fe content (mg kg⁻¹) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	D	M	S	Range	Mean	D	M	S
1	28	15.43-81.19	47.00	0.0	0.0	100	11.37-73.69	38.81	0.0	0.0	100
2	27	29.01-80.89	52.53	0.0	0.0	100	23.33-69.10	43.98	0.0	0.0	100
3	47	22.85-127.70	57.55	0.0	0.0	100	15.21-110.80	46.83	0.0	0.0	100
Overall	102	15.43-127.70	52.36	0.0	0.0	100	11.37-110.80	43.21	0.0	0.0	100
D= Deficit (<5 mg kg ⁻¹) , M= Marginal (5-10 mg kg ⁻¹) and S=Sufficient (>10 mg kg ⁻¹)											

Table 4.14: Range and mean of available Mn content (mg kg⁻¹) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	D	M	S	Range	Mean	D	M	S
1	28	20.49-43.49	30.77	0.0	0.0	100	13.03-32.26	20.24	0.0	0.0	100
2	27	16.77-39.97	30.71	0.0	0.0	100	13.16-33.94	22.23	0.0	0.0	100
3	47	22.47-46.32	31.93	0.0	0.0	100	12.13-36.23	24.05	0.0	0.0	100
Overall	102	16.77-46.32	31.14	0.0	0.0	100	12.13-36.23	22.17	0.0	0.0	100
D= Deficit (<5 mg kg ⁻¹) , M= Marginal (5-10 mg kg ⁻¹) and S=Sufficient (>10 mg kg ⁻¹)											

Table 4.15: Range and mean of available Cu content (mg kg⁻¹) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	D	M	S	Range	Mean	D	M	S
1	28	3.63-11.35	7.44	0.0	0.0	100	2.65-7.00	4.96	0.0	0.0	100
2	27	3.07-14.49	8.93	0.0	0.0	100	2.45-9.55	6.21	0.0	0.0	100
3	47	5.00-16.36	8.34	0.0	0.0	100	2.55-14.63	6.31	0.0	0.0	100
Overall	102	5.00-16.36	8.24	0.0	0.0	100	2.45-14.63	5.83	0.0	0.0	100
D= Deficit (<0.2 mg kg ⁻¹), M= Marginal (0. 2-0.4 mg kg ⁻¹) and S=Sufficient (>0.4 mg kg ⁻¹)											

Table 4.16: Range and mean of available Zn content (mg kg⁻¹) in surface and sub-surface soil samples and their distribution into different classes

Profile Number	Number of samples	Depth (cm)									
		0-20		Classes (%)			20-40		Classes (%)		
		Range	Mean	D	M	S	Range	Mean	D	M	S
1	28	0.51-2.12	0.98	0.0	60.71	39.29	0.38-1.75	0.78	14.29	75.0	10.71
2	27	0.74-2.74	1.37	0.0	22.22	77.78	0.41-1.77	1.00	11.11	55.56	33.33
3	47	0.50-2.41	1.26	0.0	25.93	74.07	0.36-2.24	0.91	17.02	53.19	29.79
Overall	102	0.50-2.74	1.20	0.0	36.15	63.85	0.36-2.24	0.90	14.14	61.25	24.61
D= Deficient (<0.5 mg kg ⁻¹), M= Marginal (0. 5-1.0 mg kg ⁻¹) and S=Sufficient (>1.0 mg kg ⁻¹)											

the all profile area. So, the need of nitrogen is more in the profile area 2 followed by the profile area 3 and 1.

Available potassium is showing high nutrient index in all the study areas in the surface soils, however, in the sub-surface layer it is showing medium fertility status in the profile area 1 and 2 but in the area of profile 3, it is high. Overall, it can be said that soils of the study area are having good supply of potassium.

Available sulphur is also showing high fertility status of the soils throughout the study area at both the surface and sub-surface layer except it was found medium at the sub-surface soils of the profile area 2.

Zinc is having high fertility status at the surface soils of profile area 1 and 2, while it has medium fertility status in the profile area 3. In the case of sub-surface soils layer, throughout the study area there is medium fertility status of the available zinc. So, zinc fertility status is one of the major concerns in the study area, where the soils are rich in all other macro and micro-nutrients except the nitrogen. So, better nitrogen and zinc management is required to make the soil more productive.

Table 4.17: Nutrient Index of respective profile area

Profile area 1					Profile area 2				Profile area 3			
	0-20cm		20-40cm		0-20cm		20-40cm		0-20cm		20-40cm	
Nutrient	NI	Fertility status	NI	Fertility status	NI	Fertility status	NI	Fertility status	NI	Fertility status	NI	Fertility status
OC	2.93	High	2.61	High	2.85	High	2.56	High	2.96	High	2.72	High
N	1.79	Medium	1.0	Low	1.19	Low	1.0	Low	2.40	High	1.0	Low
P₂O₅	3.0	High	3.0	High	2.89	High	2.89	High	2.96	High	2.89	High
K₂O	2.64	High	2.32	Medium	2.59	High	2.30	Medium	2.70	High	2.34	High
S	3.0	High	2.75	High	2.63	High	2.30	Medium	2.83	High	2.47	High
Fe	3.0	High	3.0	High	3.0	High	3.0	High	3.0	High	3.0	High
Mn	3.0	High	3.0	High	3.0	High	3.0	High	3.0	High	3.0	High
Cu	3.0	High	3.0	High	3.0	High	3.0	High	3.0	High	3.0	High
Zn	2.39	High	1.96	Medium	2.78	High	2.22	Medium	2.74	Medium	2.13	Medium
<1.67=Low, 1.67-2.33=Medium and >2.33= High												

4.1.2.4 Simple correlations

Simple correlation among physico-chemical and chemical properties of surface and sub-surface soils of respected profile areas are presented in here (Tables 18, 19 and 20).

Soil Reaction

The result revealed that soil pH was positively and significantly correlated with EC ($r=0.465^*$), ESP ($r=0.665^{**}$), and S ($r=0.384^*$), in the surface soils of the profile area 1, ESP ($r=0.436^*$), in the profile area 2 and ESP ($r=0.293^*$), CEC ($r=0.529^{**}$), K_2O ($r=0.335^*$) in the profile area 3, while it was negative and significantly correlated with Mn ($r=-0.468^*$) and Fe($r=-0.464^*$) in the profile area 1 and in the profile area 3 with Mn ($r=-0.300^*$) and Cu ($r=-0.363^*$). In the case of sub-surface soils pH was positively and significantly correlated with EC ($r=0.542^{**}$), ESP ($r=0.523^{**}$) and K_2O ($r=0.535^{**}$) in the profile area 1, with EC ($r=0.601^{**}$) and ESP ($r=0.635^{**}$) in the profile area 2 and with ESP ($r=0.468^{**}$) in the profile area 3 while, it was negatively and significantly correlated with N ($r=-0.487^{**}$) in the profile area 1 and in the profile area 3 with P_2O_5 ($r=-0.351^*$), Fe ($r=-0.530^{**}$), Mn ($r=-0.589^{**}$), Cu ($r=-0.304^*$) and Zn ($r=-0.488^{**}$).

Soil Salinity

EC was positively and significantly correlated with pH ($r=0.465^*$) and ESP ($r=0.501^{**}$) in the surface soils of the profile area 1, with OC ($r=0.465^*$), ESP ($r=0.752^{**}$) and S ($r=0.849^{**}$) in the profile area 2 and with OC ($r=0.386^*$) and N ($r=0.509^*$) in the profile area 3 while, it was negatively and significantly correlated with P_2O_5 ($r=-0.300^*$) and Zn ($r=-0.319^*$) in the profile area 3. In the case of sub-surface soils EC was positively and significantly

correlated with pH ($r=0.542^{**}$), ESP ($r=0.698^{**}$) and S ($r=0.479^{**}$) in the profile area 1, with pH ($r=0.601^{**}$), ESP ($r=0.920^{**}$) and S ($r=0.791^{**}$) in the profile area 2 and with OC ($r=0.346^*$), ESP ($r=0.315^*$) and S ($r=0.4395^{**}$) in the profile area 3.

Organic Carbon

OC was positively and significantly correlated with N ($r=0.660^{**}$), S ($r=0.498^{**}$) and Cu ($r=0.497^{**}$) in the surface soils of the profile area 1, with EC ($r=0.465^*$), N ($r=0.752^{**}$), S ($r=0.544^{**}$) and Cu ($r=0.590^{**}$) in the profile area 2 and with EC ($r=0.386^{**}$), N ($r=0.792^{**}$) and Fe ($r=0.531^{**}$) in the profile area 3. While, it is negatively and significantly correlated with ESP ($r=-0.395^*$) and K_2O ($r=-0.414^*$) in the profile area 1. In the case of sub-surface soils OC was positively and significantly correlated with N ($r=0.512^{**}$), S ($r=0.590^{**}$) and Cu ($r=0.706^{**}$) in the profile area 1, with N ($r=0.745^{**}$), P_2O_5 ($r=0.549^{**}$), Mn ($r=0.528^{**}$), Cu ($r=0.658^{**}$) and Zn ($r=0.470^*$) in the profile area 2 and with EC ($r=0.346^*$), N ($r=0.556^{**}$), P_2O_5 ($r=0.308^*$), S ($r=0.391^{**}$), Fe ($r=0.582^{**}$) Cu ($r=0.712^{**}$) and Zn ($r=0.318^*$) in the profile area 3.

Soil Sodicity

ESP was positively and significantly correlated with pH ($r=0.436^*$), EC ($r=0.753^{**}$) and S ($r=0.616^{**}$) in the surface soils of the profile area 2 and with pH ($r=0.293^*$) in the profile area 3, while it was negatively and significantly correlated with N ($r=-0.382^*$), Fe ($r=-0.522^{**}$) and Cu ($r=-0.527^{**}$) in the profile area 1, with Fe ($r=-0.419^*$) in the profile area 2 and with Zn ($r=-0.4339^*$) in the profile area 3. In the case of sub-surface soils ESP was positively and significantly correlated with pH ($r=0.635^{**}$), EC

($r=0.920^{**}$) and S ($r=0.722^{**}$) in the profile area 2, and with pH ($r=0.468^{**}$) and EC ($r=-0.315^{*}$) in the profile area 3, while it is negatively and significantly correlated with Fe ($r=-0.486^{**}$) in the profile areas of 1, with Fe ($r=-0.435^{*}$) in the profile area 2 and with Zn ($r=-0.339^{*}$) in the profile area 3.

Cation Exchange Capacity

CEC was positively and significantly correlated with pH ($r=0.529^{**}$) in the surface soils of the profile area 3, while it was negatively and significantly correlated with Zn ($r=-0.468^{*}$) in the profile area 1, with K_2O ($r=-0.462^{*}$) in the profile area 2. In the case of sub-surface soils CEC was negatively and significantly correlated with N ($r=-0.509^{**}$) and Zn ($r=-0.481^{**}$) in the profile area 1, with Cu ($r=0.402^{*}$) in the profile area 2 and with Zn ($r=-0.339^{*}$) in the profile area 3.

Available Nitrogen

N was positively and significantly correlated with OC ($r=0.660^{**}$), S ($r=0.393^{*}$), Fe ($r=0.404^{*}$) and Cu ($r=0.394^{*}$) in the surface soils of the profile area 1, with OC ($r=0.752^{**}$) and Cu ($r=0.570^{**}$) in the profile area 2 and with EC ($r=0.509^{**}$), OC ($r=0.792^{**}$) and Fe ($r=0.510^{**}$) in the profile area 3, while it was negatively and significantly correlated with ESP ($r=-0.382^{*}$) and K_2O ($r=-0.394^{*}$) in the profile area 1. In the case of sub-surface soils N was positively and significantly correlated with OC ($r=0.512^{**}$) and Cu ($r=0.570^{**}$) in the profile area 1, with OC ($r=0.745^{**}$), P_2O_5 ($r=0.557^{**}$) and S ($r=0.516^{**}$) in the profile area 2 and with OC ($r=0.556^{**}$), Cu ($r=0.477^{**}$) and Zn ($r=0.450^{**}$) in the profile area 3, while it was negatively and significantly

correlated with pH ($r=-0.487^{**}$) and CEC ($r=0.509^{**}$) in the profile area 1.

Available Phosphorus

P_2O_5 was positively and significantly correlated with Fe ($r=0.424^*$) in the surface soils of the profile area 1, with Mn ($r=0.465^*$) and Zn ($r=0.718^{**}$) in the profile area 2, while it was negatively and significantly correlated with EC ($r=0.300^*$) in the profile area 3. In the case of sub-surface soils P_2O_5 was positively and significantly correlated with K_2O ($r=0.395^*$) in the profile area 1, with OC ($r=0.549^{**}$), N ($r=0.577^{**}$) and Zn ($r=0.749^{**}$) in the profile area 2 and with OC ($r=0.308^*$), Fe ($r=0.386^*$) and Zn ($r=0.360^*$) in the profile area 3, while it was negatively and significantly correlated with pH ($r=-0.351^*$) in the profile area 3.

Available Potassium

K_2O was positively and significantly correlated with Fe ($r=0.465^*$) and Zn ($r=0.718^{**}$) in the surface soils of the profile area 2 and with pH ($r=0.4335^*$) in the profile 3, while it was negatively and significantly correlated with OC ($r=-0.414^*$), N ($r=-0.394^*$) and Fe ($r=-0.532^{**}$) in the profile area 1, with CEC ($r=-0.462^*$) in the profile area 2. In the case of sub-surface soils K_2O was positively and significantly correlated with pH ($r=0.4535^{**}$) and P_2O_5 ($r=0.395^*$) in the profile area 1, with Zn ($r=0.749^{**}$) in the profile area 2 while, it was negatively and significantly correlated with Mn ($r=-0.359^*$) in the profile area 3.

Available Sulphur

S was positively and significantly correlated with pH ($r=0.384^*$), OC ($r=0.498^{**}$) and N ($r=0.393^*$) in the surface soils of the profile area 1, with EC ($r=0.849^{**}$), OC ($r=0.544^{**}$) and

ESP ($r=0.616^{**}$) in the profile area 2 and with CEC ($r=0.369^*$) in the profile area 3. In the case of sub-surface soils S was positively and significantly correlated with EC ($r=0.479^{**}$), OC ($r=0.590^{**}$) and Cu ($r=0.480^{**}$) in the profile area 1, with EC ($r=0.791^{**}$), ESP ($r=0.722^{**}$) and N ($r=0.516^{**}$) in the profile area 2 and with EC ($r=0.395^{**}$), OC ($r=0.391^{**}$) and Cu ($r=0.335^*$) in the profile area 3 while, it was negatively and significantly correlated with Zn ($r=-0.409^*$) in the profile area 1.

Available Iron

Fe was positively and significantly correlated with N ($r=0.403^*$), P_2O_5 ($r=0.424^*$) and Cu ($r=0.453^*$) in the surface soils of the profile area 1, with OC ($r=0.531^{**}$), N ($r=0.510^{**}$) and Mn ($r=0.400^{**}$) in the profile area 3 and while, it was negatively and significantly correlated with pH ($r=-0.464^*$) and ESP ($r=-0.522^{**}$) in the profile area 1, with ESP ($r=-0.419^*$) in the profile area 2. In the case of sub-surface soils Fe was positively and significantly correlated with Cu ($r=0.608^{**}$) in the profile area 1 and with OC ($r=0.4530^{**}$), P_2O_5 ($r=0.386^{**}$), Mn ($r=0.293^*$), Cu ($r=0.367^*$) and Zn ($r=0.321^*$) in the profile area 3 while, it was negatively and significantly correlated with ESP ($r=-0.486^*$) in the profile area 1, with ESP ($r=-0.435^*$) in the profile area 2 and with pH ($r=0.530^{**}$) in the profile area 3.

Available Manganese

Mn was positively and significantly correlated with P_2O_5 ($r=0.465^*$) and Cu ($r=0.429^*$) in the surface soils of the profile area 2 and with Fe ($r=0.400^{**}$) in the profile area 3 while, it was negatively and significantly correlated with pH ($r=-0.468^*$) and K_2O ($r=-0.532^{**}$) in the profile area 1, with K_2O ($r=-0.443^*$) in the

profile area 2 and with pH ($r=-0.300^*$) and CEC ($r=0.427^{**}$) in the profile area 3. In the case of sub-surface soils Mn was positively and significantly correlated with OC ($r=0.528^{**}$) and Cu ($r=0.622^{**}$) in the profile area 2 and with Fe ($r=0.293^*$) in the profile area 3 while, it was negatively and significantly correlated with pH ($r=-0.589^*$) and K_2O ($r=-0.359^*$) in the profile area 3.

Available Copper

Cu was positively and significantly correlated with OC ($r=0.497^{**}$), N ($r=0.94^*$), Fe ($r=0.453^*$) and Zn ($r=0.457^*$) in the surface soils of the profile area 1, with OC ($r=0.590^{**}$), N ($r=0.570^{**}$) and Mn ($r=0.429^*$) in the profile area 2 while, it was negatively and significantly correlated with ESP ($r=-0.527^{**}$) in the profile area 1 and with pH ($r=-0.363^*$) in the profile area 3. In the case of sub-surface soils Cu was positively and significantly correlated with OC ($r=0.706^{**}$), N ($r=0.594^{**}$), S ($r=0.480^{**}$) and Fe ($r=0.608^{**}$) in the profile area 1, with OC ($r=0.658^{**}$), Mn ($r=0.662^{**}$) and Zn ($r=0.427^*$) in the profile area 2 and with OC ($r=0.712^{**}$), N ($r=0.4677^{**}$), S ($r=0.335^*$) and Fe ($r=0.4367^*$) in the profile area 3 while, it was negatively and significantly correlated with CEC ($r=-0.402^*$) in the profile area 2 and with pH ($r=-0.304^*$) in the profile area 3.

Available Zinc

Zn was positively and significantly correlated with Cu ($r=0.457^*$) in the surface soils of the profile area 1, with P_2O_5 ($r=0.749^{**}$) in the profile area 2 while, it was negatively and significantly correlated with CEC ($r=-0.468^*$) in the profile area 1 and with EC ($r=-0.319^*$) in the profile area 3. In the case of sub surface soils Zn was positively and significantly correlated with OC

($r=0.470^*$), P_2O_5 ($r=0.749^{**}$) and Cu ($r=0.427^*$) in the profile area 2 and with OC ($r=0.318^*$), N ($r=0.450^{**}$), P_2O_5 ($r=0.360^*$) and Fe ($r=0.321^*$) in the profile area 3 while, it was negatively and significantly correlated with CEC ($r=-0.481^{**}$) and S($r=-0.409^*$) in the profile area 1 and in the profile area 3 with pH ($r=-0.488^{**}$) and ESP ($r=-0.339^*$).

Present results on simple correlation were supported by the findings of Thakur *et al.* (2011) and Chouhan *et al.* (2012) and Singh *et al.* (2014). In case of Vertisol from Jabalpur, Thakur *et al.* (2011) reported that SOC content exhibited significant positive correlation with available Fe (0.62^{**}), Mn (0.65^{**}) and Cu (0.69^{**}) contents of the surface soil (0-20 cm) which were in the same line as obtained in the present study. Further, the present results also corroborated with findings of Thakur *et al.* (2011), whereby they mentioned that soil pH had significant negative association with micronutrient cations i.e. Zn ($r=-0.65^{**}$), Fe ($r=-0.65^{**}$), Mn ($r=-0.46^*$) and Cu ($r=-0.51^*$) in 20-40 cm soil layer. Chouhan *et al.* (2012) reported that pH had negative correlation with DTPA-Cu ($r=0.371^{**}$), DTPA-Fe ($r=0.683^{**}$), DTPA-Mn ($r=0.683^{**}$) while organic carbon had positive relationship with DTPA-Zn ($r=0.353^{**}$), DTPA-Cu ($r=0.404^{**}$), DTPA-Mn ($r=0.237^{**}$) and available S ($r=0.256^{**}$) in the medium black soils of Madhya Pradesh. Singh *et al.* (2014) observed a significant and positive correlation of available N was observed with OC ($r = 0.616^*$). Available N was negatively and significant correlated with pH ($r = -0.210^*$) and EC ($r = -0.288^*$). A significant and positive correlation of available P was observed with OC ($r = 0.507^*$). Available P was significant and negatively correlated with EC ($r = -$

0.210*) and pH ($r = -0.513^*$). A significant and positive correlation of available K was observed between OC ($r = 0.426^*$) and EC ($r = 0.221^*$). Available K showed negative and non-significant correlation with pH ($r = -0.097$) and CaCO_3 ($r = -0.026$). A significant positive correlation of available S was observed between EC ($r = 0.671^*$) and OC ($r = 0.482^*$). Available S was negatively and significantly correlated with pH ($r = -0.593$) and CaCO_3 ($r = -0.196$). Available Zn was positively and significantly correlated with OC ($r = 0.775^*$); negatively and significantly correlated with pH ($r = -0.724^*$) and CaCO_3 ($r = -0.748^*$). Available Fe had significant and positive correlation with OC ($r = 0.489^*$) whereas negative and significant correlation with pH ($r = -0.516^*$) and CaCO_3 ($r = -0.615^*$). Available Cu showed significant and positive correlation with OC ($r = 0.685^*$) whereas negative and significant correlation with pH ($r = -0.710^*$) and CaCO_3 ($r = -0.704^*$). Available Mn showed significant and positive correlation with OC ($r = 0.662^*$) whereas negative and significant correlation with pH ($r = -0.603^*$) and CaCO_3 ($r = -0.669^*$).

Table 4.18: Simple correlations among different parameters of surface and sub-surface soils of profile area 1 (n=28)

	pH	EC	OC	ESP	CEC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
Surface Soil													
pH	1.00												
EC	0.465*	1.00											
OC	-0.370	0.029	1.00										
ESP	.665**	0.501**	-0.395*	1.00									
CEC	0.129	0.298	0.223	-0.013	1.00								
N	-0.159	-0.038	0.660**	-0.382*	0.158	1.00							
P₂O₅	-0.251	-0.311	-0.177	-0.125	0.088	0.177	1.00						
K₂O	0.363	-0.002	-0.414*	0.072	0.310	-0.394*	0.311	1.00					
S	0.384*	0.350	0.498**	0.214	0.318	0.393*	-0.307	-0.177	1.00				
Fe	-0.464*	-0.187	0.201	-0.522**	0.154	0.403*	0.424*	-0.074	-0.112	1.00			
Mn	-0.468*	-0.144	0.360	-0.330	-0.075	0.281	-0.021	-0.532**	0.084	0.285	1.00		
Cu	-0.362	-0.045	0.497**	-0.527**	0.176	0.394*	-0.052	0.104	0.206	0.453*	0.192	1.00	
Zn	-0.200	-0.226	-0.049	-0.141	-0.468*	-0.240	0.071	0.061	-0.204	-0.055	0.199	0.457*	1.00
Sub-surface soil													
pH	1.00												
EC	0.542**	1.00											
OC	-0.223	0.233	1.00										
ESP	0.523**	0.698**	-0.247	1.00									
CEC	0.073	0.176	0.080	0.168	1.00								
N	-0.487**	-0.070	0.512**	-0.249	-0.509**	1.00							
P₂O₅	0.160	-0.072	0.058	-0.069	0.042	0.119	1.00						
K₂O	0.535**	0.353	0.040	0.066	0.199	-0.369	0.395*	1.00					
S	-0.170	0.479**	0.590**	0.238	0.038	0.357	-0.111	-0.234	1.00				
Fe	-0.359	-0.323	0.229	-0.486**	-0.016	0.254	0.355	-0.090	-0.006	1.00			
Mn	-0.230	-0.192	-0.040	-0.175	-0.291	0.147	-0.326	-0.169	-0.062	-0.220	1.00		
Cu	-0.361	0.068	0.706**	-0.275	-0.146	0.594**	0.311	-0.084	0.480**	0.608**	-0.021	1.00	
Zn	0.163	-0.317	-0.217	-0.265	-0.481**	0.101	0.308	0.207	-0.409*	0.037	0.286	0.010	1.00
** star and * star denote significant correlation (2-tailed) at 0.01 level and 0.05 level, respectively													

Table 4.19: Simple correlations among different parameters of surface and sub-surface soils of the profile area 2 (n=27)

	pH	EC	OC	ESP	CEC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
Surface Soil													
pH	1.00												
EC	0.097	1.00											
OC	-0.195	0.465*	1.00										
ESP	0.436*	0.753**	0.237	1.00									
CEC	0.149	0.093	0.289	-0.013	1.00								
N	-0.170	0.251	0.752**	-0.025	-0.013	1.00							
P₂O₅	-0.124	0.087	0.316	0.194	0.165	-0.067	1.00						
K₂O	-0.189	-0.230	-0.186	-0.085	-0.462*	-0.027	-0.109	1.00					
S	-0.239	0.849**	0.544**	0.616**	-0.022	0.240	0.340	0.014	1.00				
Fe	-0.292	-0.057	0.135	-0.419*	-0.011	0.258	-0.267	-0.161	-0.032	1.00			
Mn	-0.040	0.177	0.257	0.279	-0.016	0.030	0.465*	-0.443*	0.145	-0.131	1.00		
Cu	-0.064	0.224	0.590**	0.253	-0.228	0.570**	0.159	0.073	0.313	-0.166	0.429*	1.00	
Zn	-0.289	-0.198	0.265	-0.120	-0.183	0.121	0.718**	0.392*	0.151	-0.275	0.146	0.270	1.00
Sub-surface soil													
pH	1.00												
EC	0.601**	1.00											
OC	-0.299	0.137	1.00										
ESP	0.635**	0.920**	0.007	1.00									
CEC	0.250	0.127	0.071	0.088	1.00								
N	-0.295	0.296	0.745**	0.188	0.151	1.00							
P₂O₅	-0.148	-0.011	0.549**	0.010	0.128	0.557**	1.00						
K₂O	-0.047	-0.105	-0.307	-0.030	-0.268	-0.281	0.036	1.00					
S	0.269	0.791**	0.275	0.722**	-0.050	0.516**	0.275	-0.106	1.00				
Fe	-0.319	-0.352	-0.116	-0.435*	-0.134	-0.064	-0.282	-0.354	-0.147	1.00			
Mn	-0.381	0.144	0.528**	0.015	-0.194	0.346	0.010	-0.228	0.137	0.063	1.00		
Cu	-0.241	0.126	0.658**	0.042	-0.402*	0.329	0.283	-0.003	0.165	-0.233	0.662**	1.00	
Zn	-0.354	-0.302	0.470*	-0.336	-0.114	0.292	0.749**	0.300	-0.031	-0.137	0.137	0.427*	1.00
** star and * star denote significant correlation (2-tailed) at 0.01 level and 0.05 level, respectively													

Table 4.20: Simple correlations among different parameters of surface and sub-surface soils of profile area 3 (n=47)

	pH	EC	OC	ESP	CEC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
Surface Soil													
pH	1.00												
EC	-0.263	1.00											
OC	-0.073	0.386**	1.00										
ESP	0.293*	0.273	-0.011	1.00									
CEC	0.529**	-0.056	0.047	-0.125	1.00								
N	-0.146	0.509**	0.792**	0.057	-0.168	1.00							
P₂O₅	0.033	-0.300*	0.251	-0.136	0.257	0.204	1.00						
K₂O	0.335*	0.012	0.157	-0.212	0.121	0.118	-0.228	1.00					
S	0.114	0.240	0.165	0.118	0.369*	0.111	-0.209	-0.144	1.00				
Fe	-0.201	0.135	0.531**	0.190	-0.206	0.510**	0.126	-0.044	0.011	1.00			
Mn	-0.300*	0.044	0.053	0.181	-0.427**	0.192	0.020	-0.231	-0.236	0.400**	1.00		
Cu	-0.363*	0.147	0.215	0.101	-0.079	0.033	-0.203	0.139	0.262	0.209	-0.031	1.00	
Zn	0.039	-0.319*	-0.120	-0.154	0.081	-0.158	0.146	0.099	-0.119	0.071	0.029	0.007	1.00
Sub-surface soil													
pH	1.00												
EC	0.229	1.00											
OC	-0.286	0.346*	1.00										
ESP	0.468**	0.315*	-0.176	1.00									
CEC	0.248	-0.112	0.020	0.109	1.00								
N	-0.203	-0.244	0.556**	-0.134	0.103	1.00							
P₂O₅	-0.351*	-0.147	0.308*	-0.225	0.017	0.234	1.00						
K₂O	-0.006	-0.051	0.276	-0.204	-0.059	0.172	-0.123	1.00					
S	0.075	0.395**	0.391**	0.036	0.255	0.011	-0.188	-0.049	1.00				
Fe	-0.530**	0.169	0.582**	-0.135	-0.078	0.184	0.386**	0.023	0.122	1.00			
Mn	-0.589**	-0.028	-0.013	-0.159	-0.240	0.007	0.091	-0.359*	-0.034	0.293*	1.00		
Cu	-0.304*	0.118	0.712**	-0.149	-0.014	0.477**	0.062	0.286	0.335*	0.367*	0.080	1.00	
Zn	-0.488**	-0.283	0.318*	-0.339*	-0.200	0.450**	0.360*	0.093	-0.062	0.321*	0.060	0.129	1.00
** star and * star denote significant correlation (2-tailed) at 0.01 level and 0.05 level, respectively													

4.1.2.5 Soil fertility map

For the better understanding of the distribution of different fertility parameters in the soils different thematic maps in relation to soil fertility status were generated using GIS based Arc View 3.2a software. Soils are generally grouped in to the various fertility classes by following standard procedures. But in the cases where there is similar fertility status throughout the study area, soils are grouped under spatial variability classification system by the software, which helps to identify accurate distribution of the fertility parameter. The thematic fertility maps generated will help in the allocating STCR based fertilizer doses recommendation on grid pint basis. The polygon ID displayed on fertility maps representing different block numbers are presented in table 3.1 will be useful in identifying individual block numbers of the village.

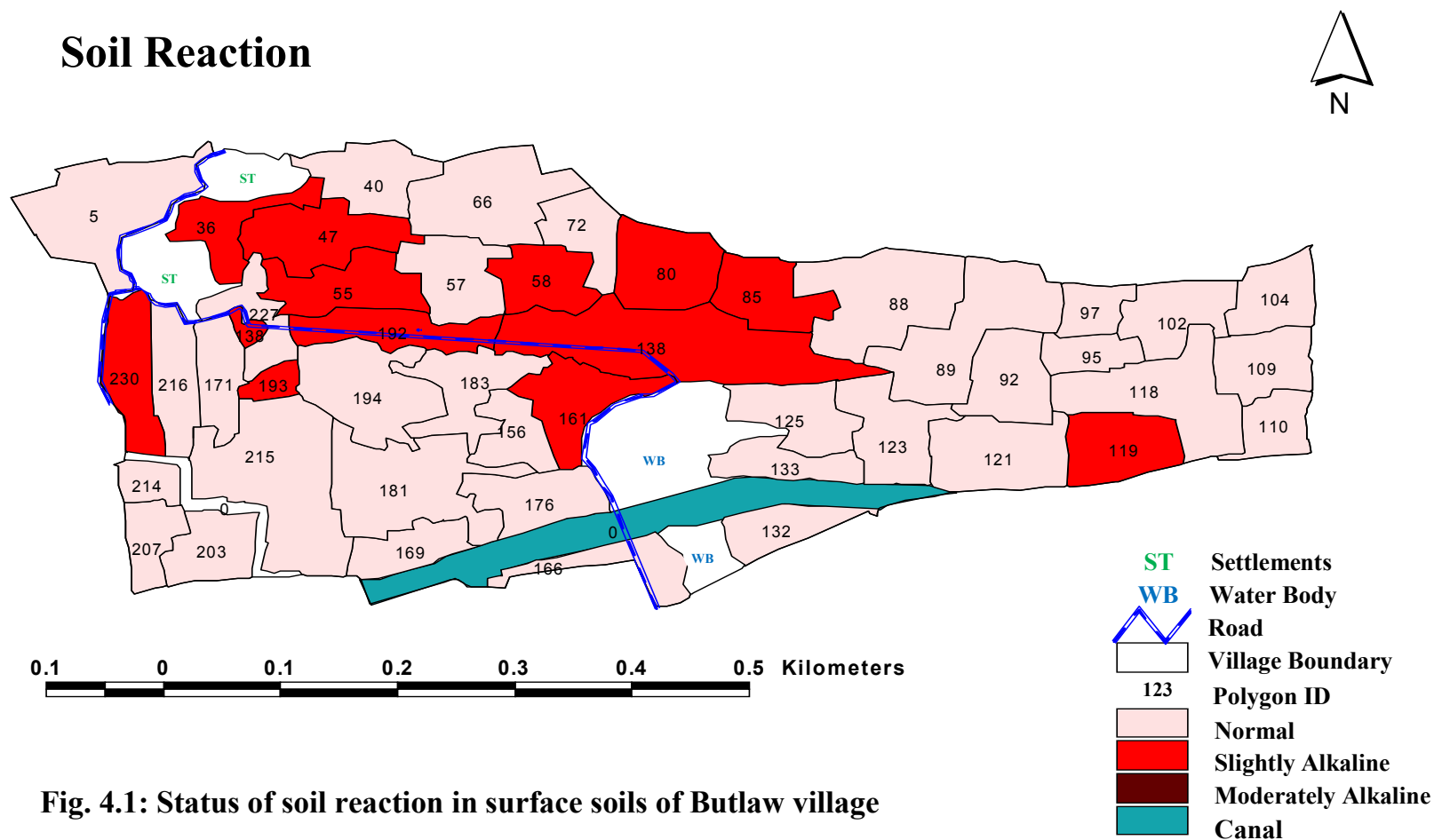


Fig. 4.1: Status of soil reaction in surface soils of Butlaw village

Soil Salinity

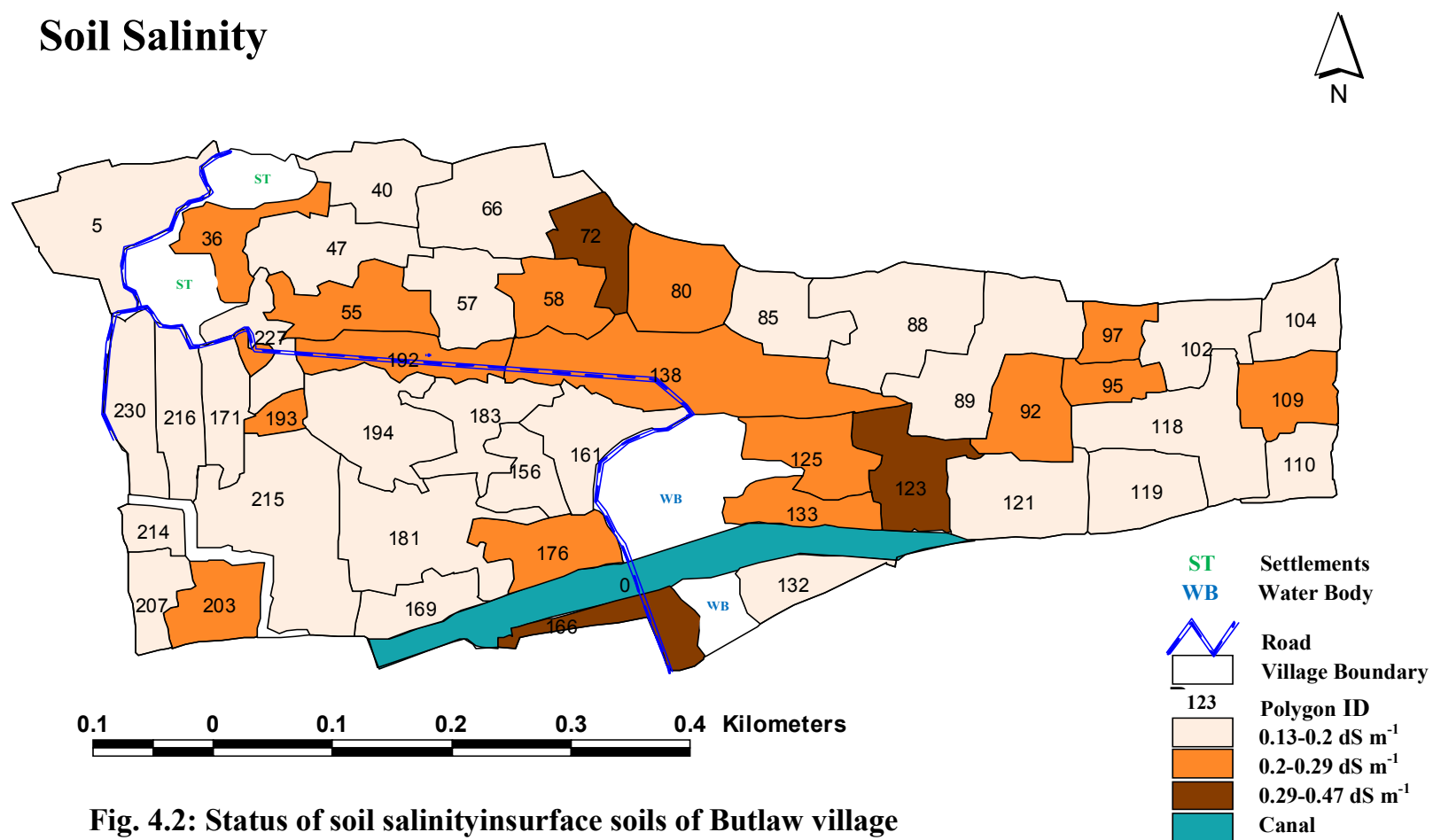


Fig. 4.2: Status of soil salinity in surface soils of Butlaw village

Organic Carbon

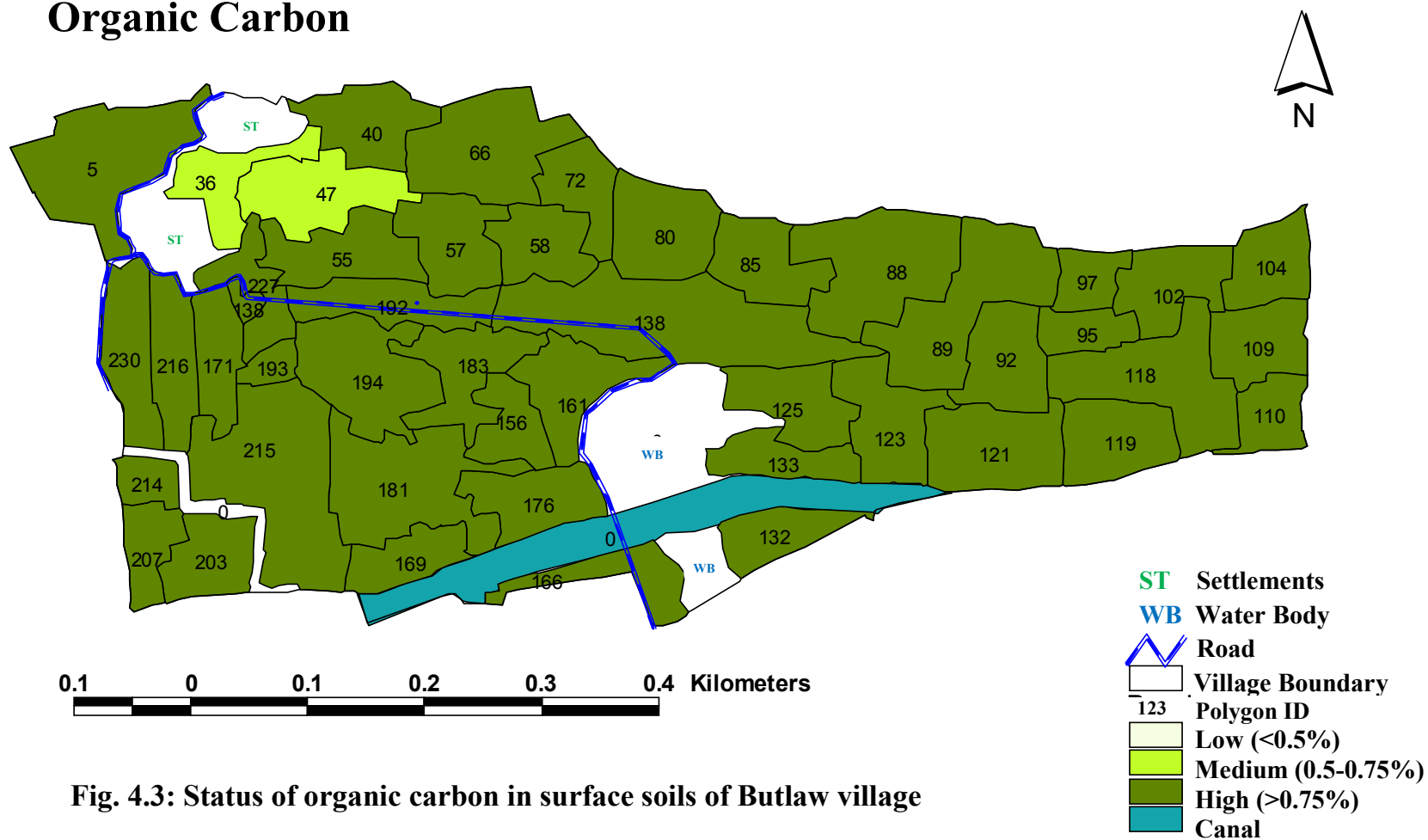
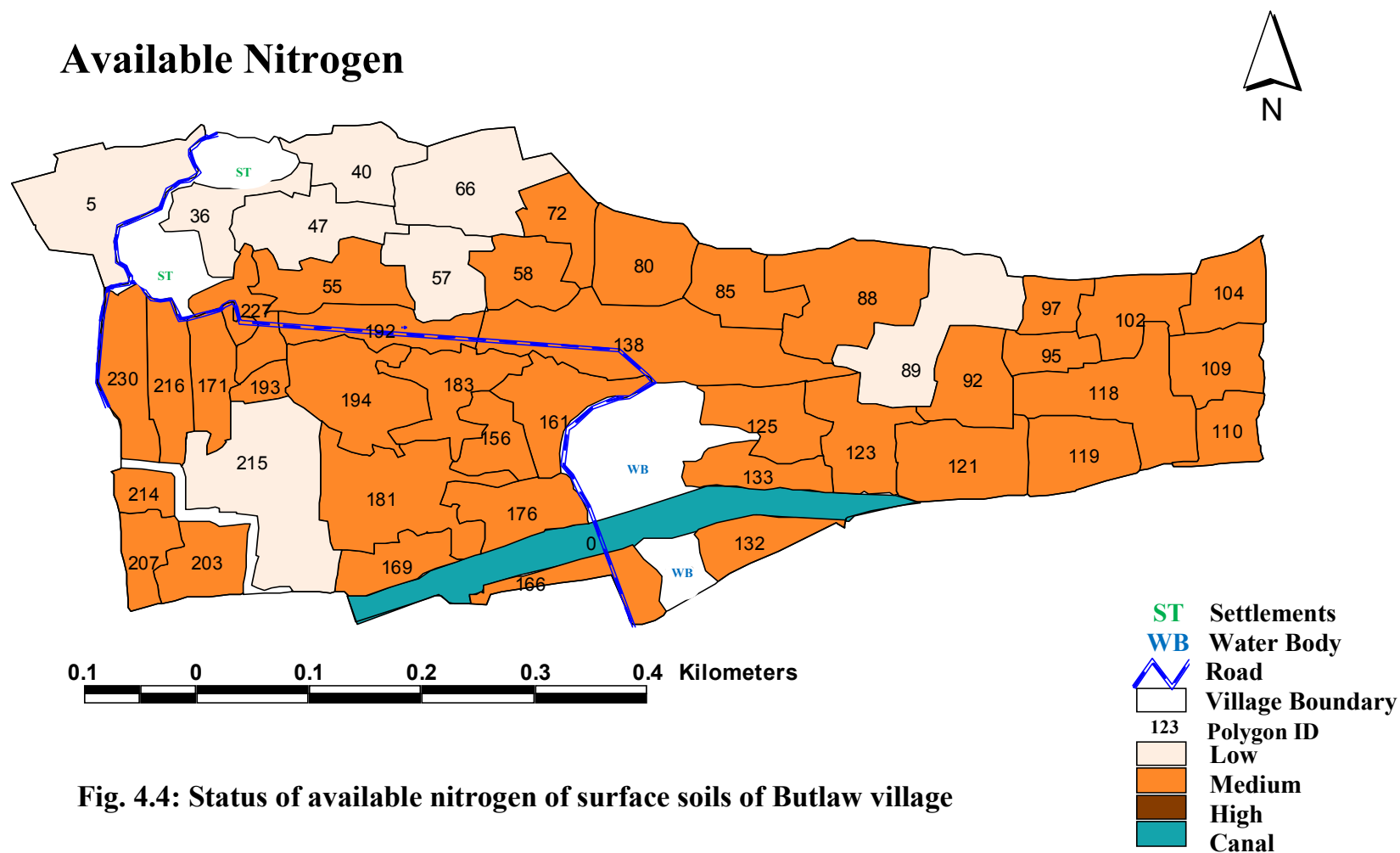


Fig. 4.3: Status of organic carbon in surface soils of Butlaw village

Available Nitrogen



Available Phosphorus

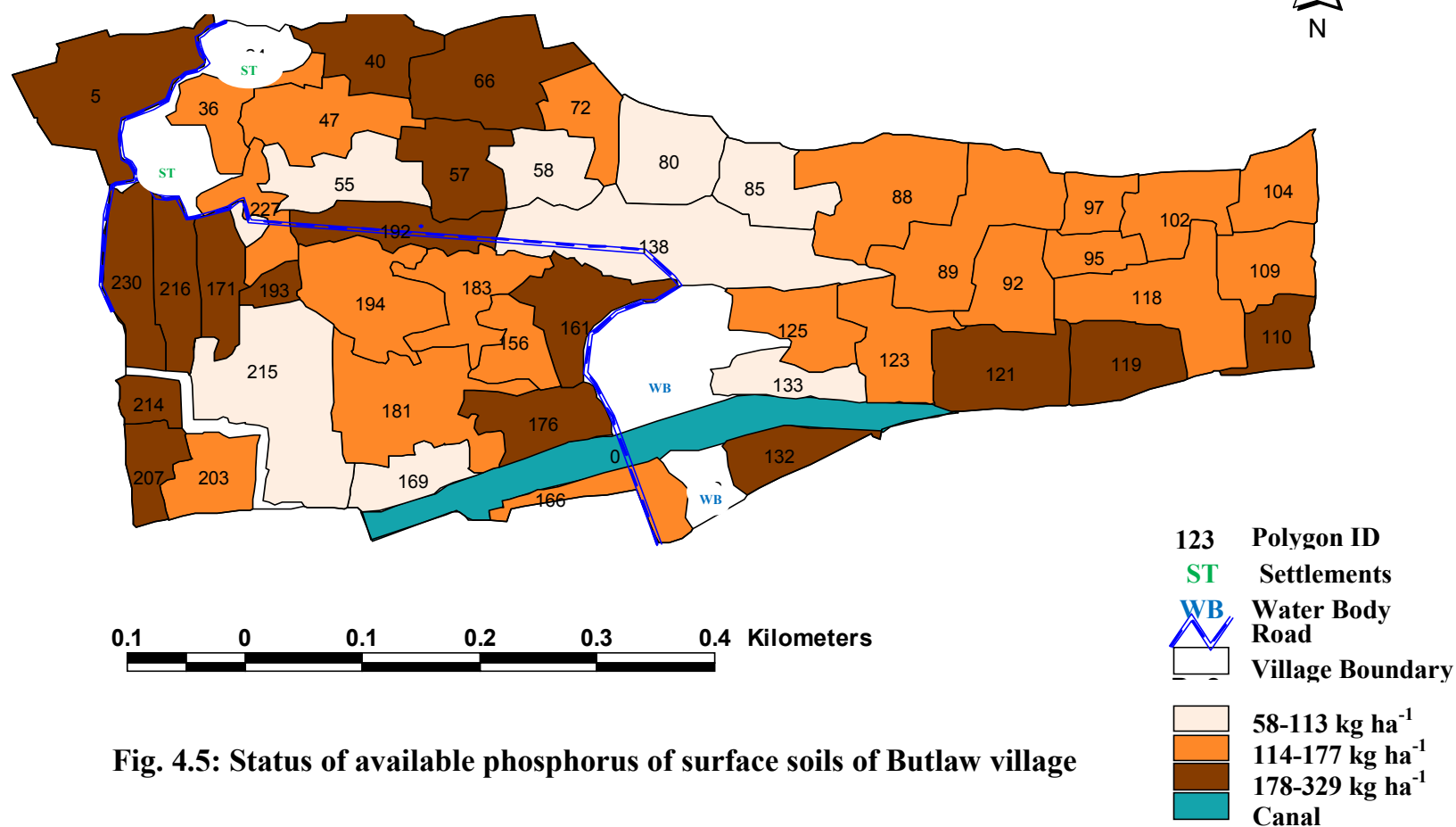


Fig. 4.5: Status of available phosphorus of surface soils of Butlaw village

Available Potassium

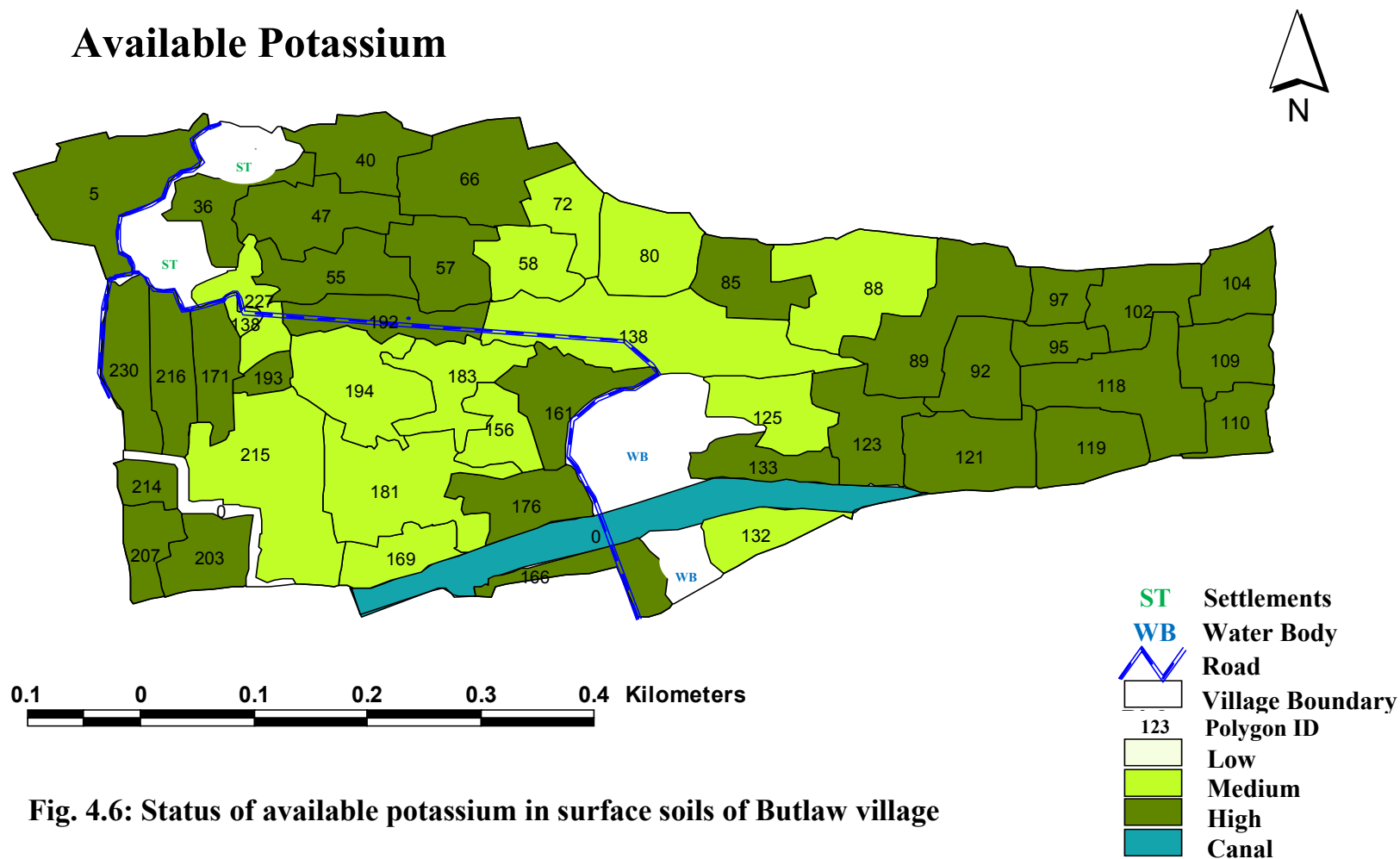
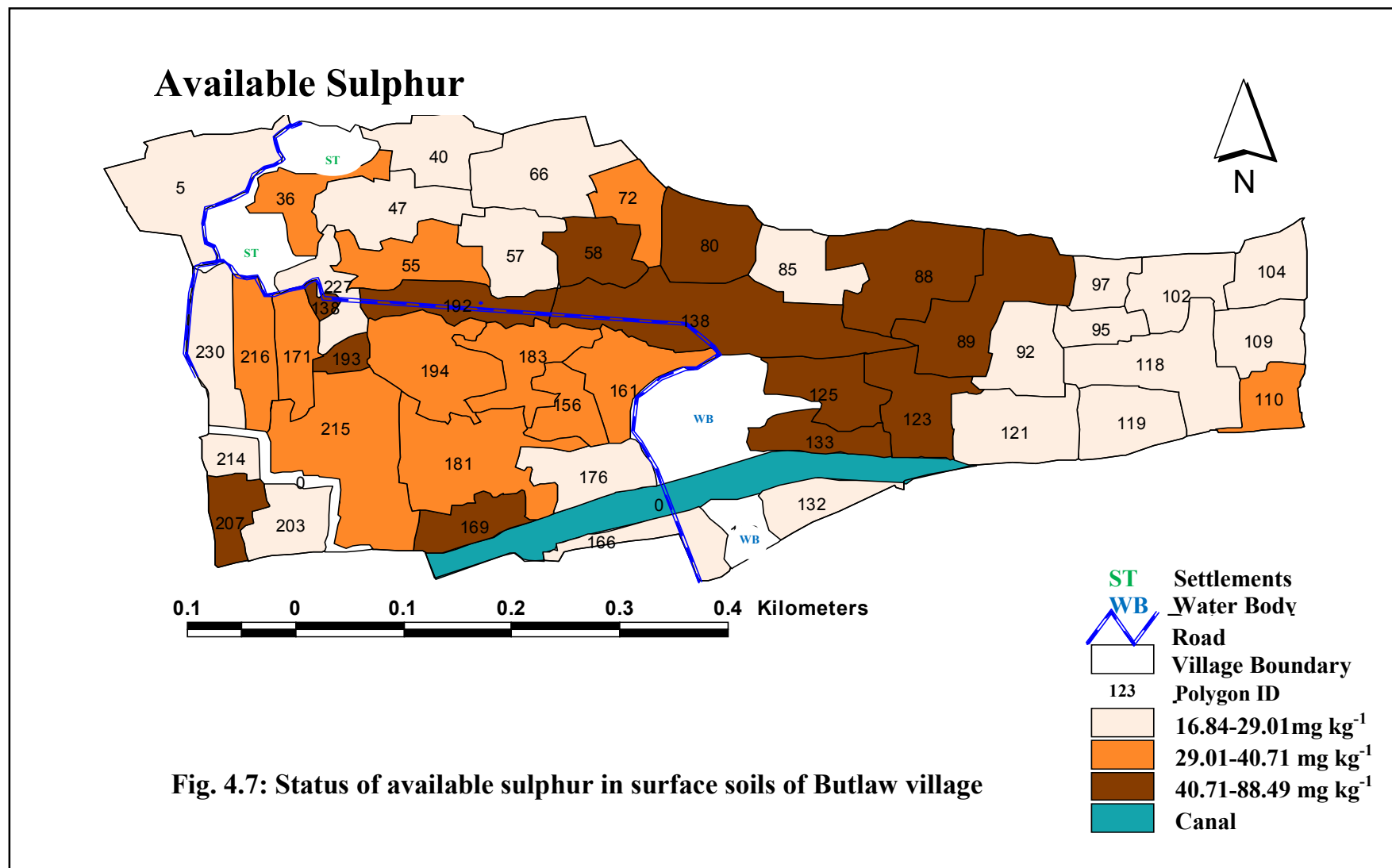
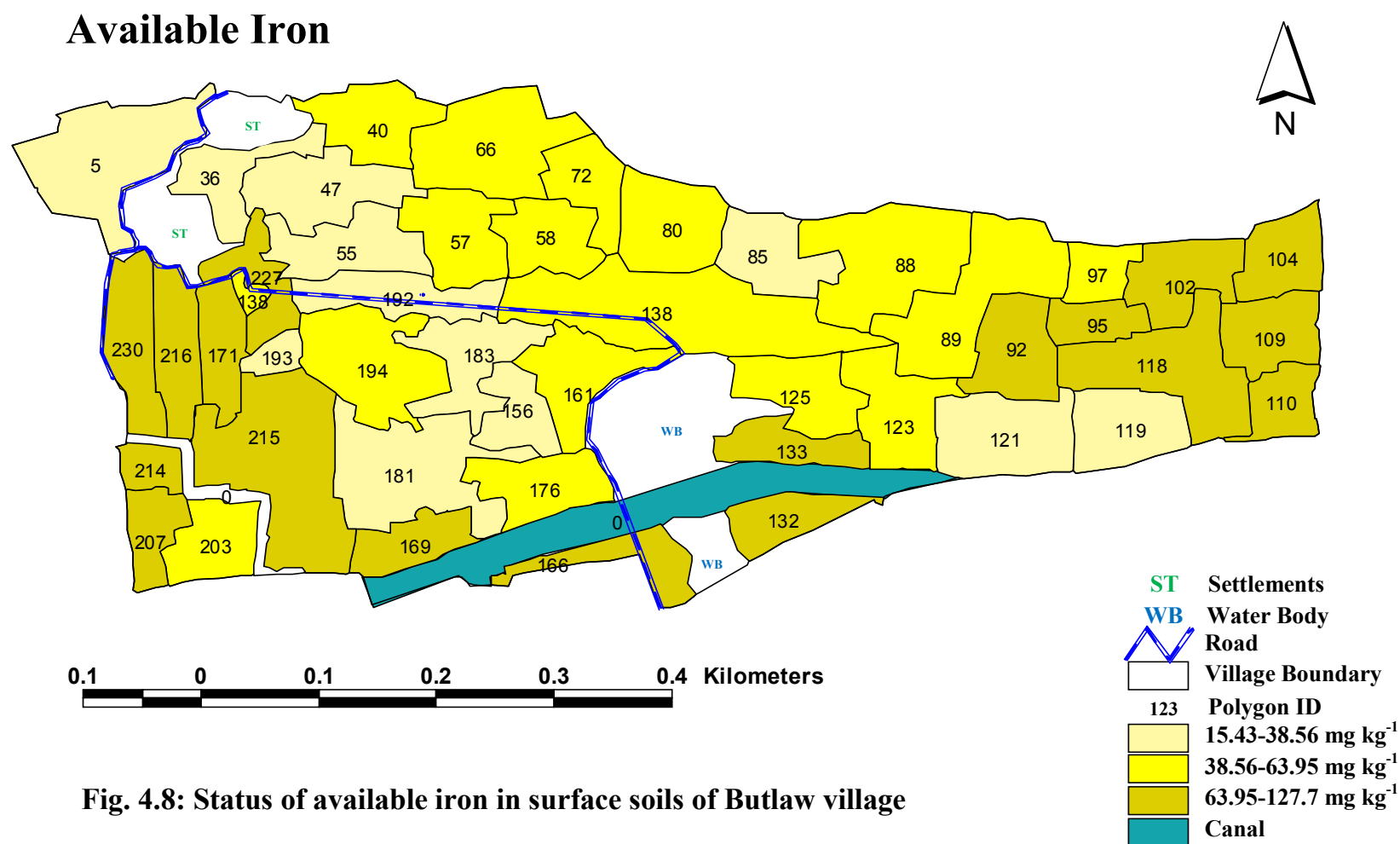


Fig. 4.6: Status of available potassium in surface soils of Butlaw village





Available Manganese

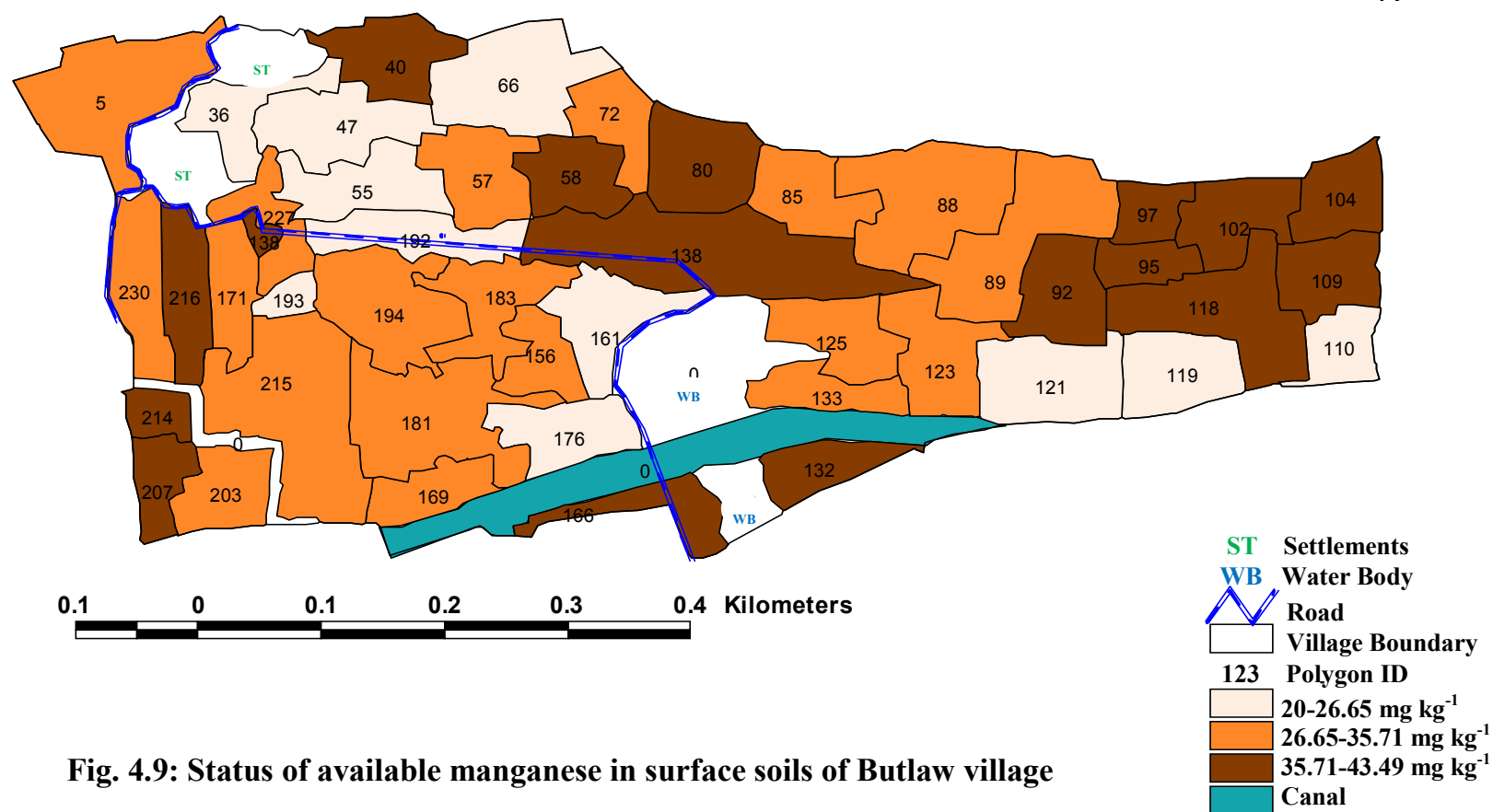


Fig. 4.9: Status of available manganese in surface soils of Butlaw village

Available Copper

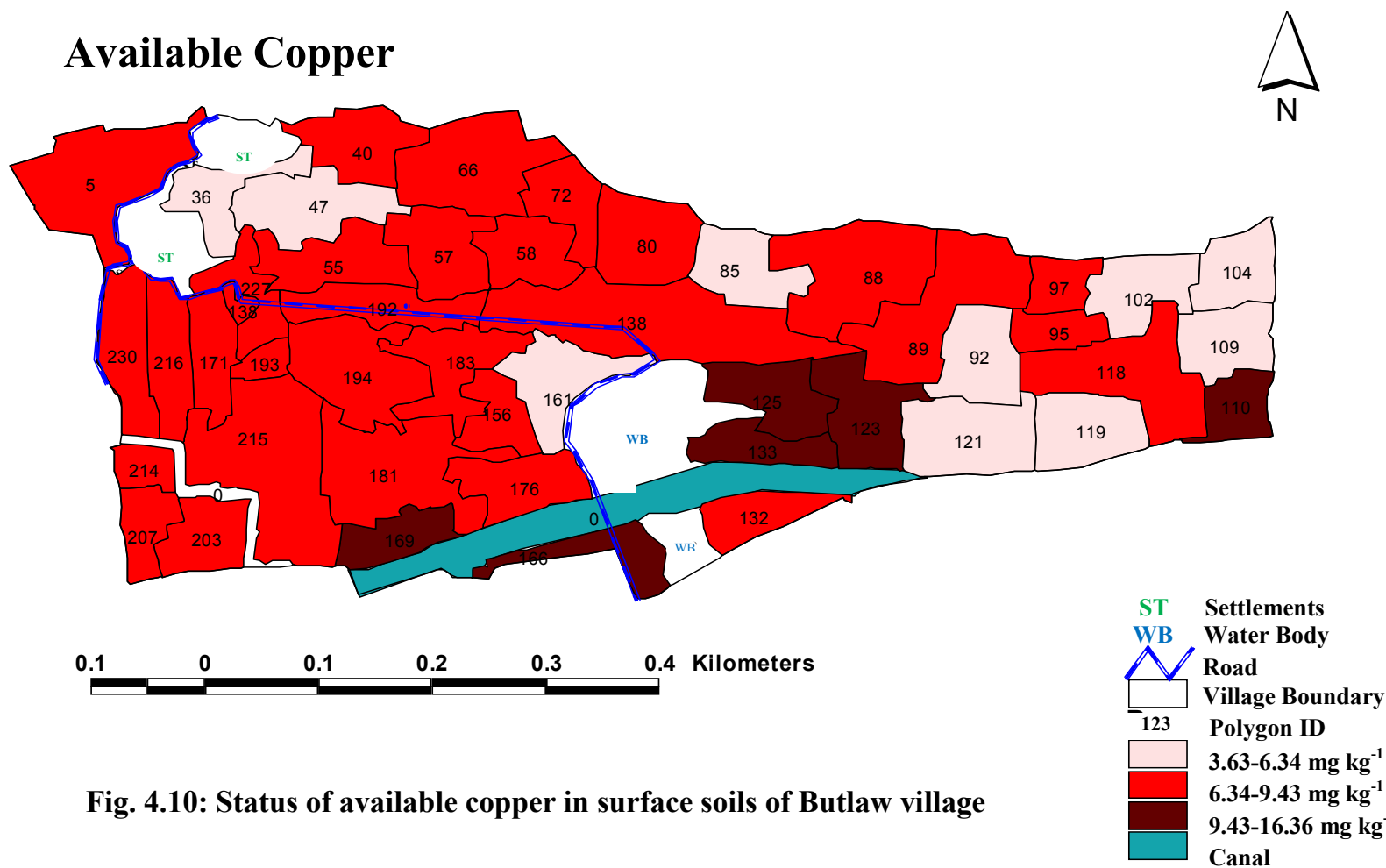


Fig. 4.10: Status of available copper in surface soils of Butlaw village

Available Zinc

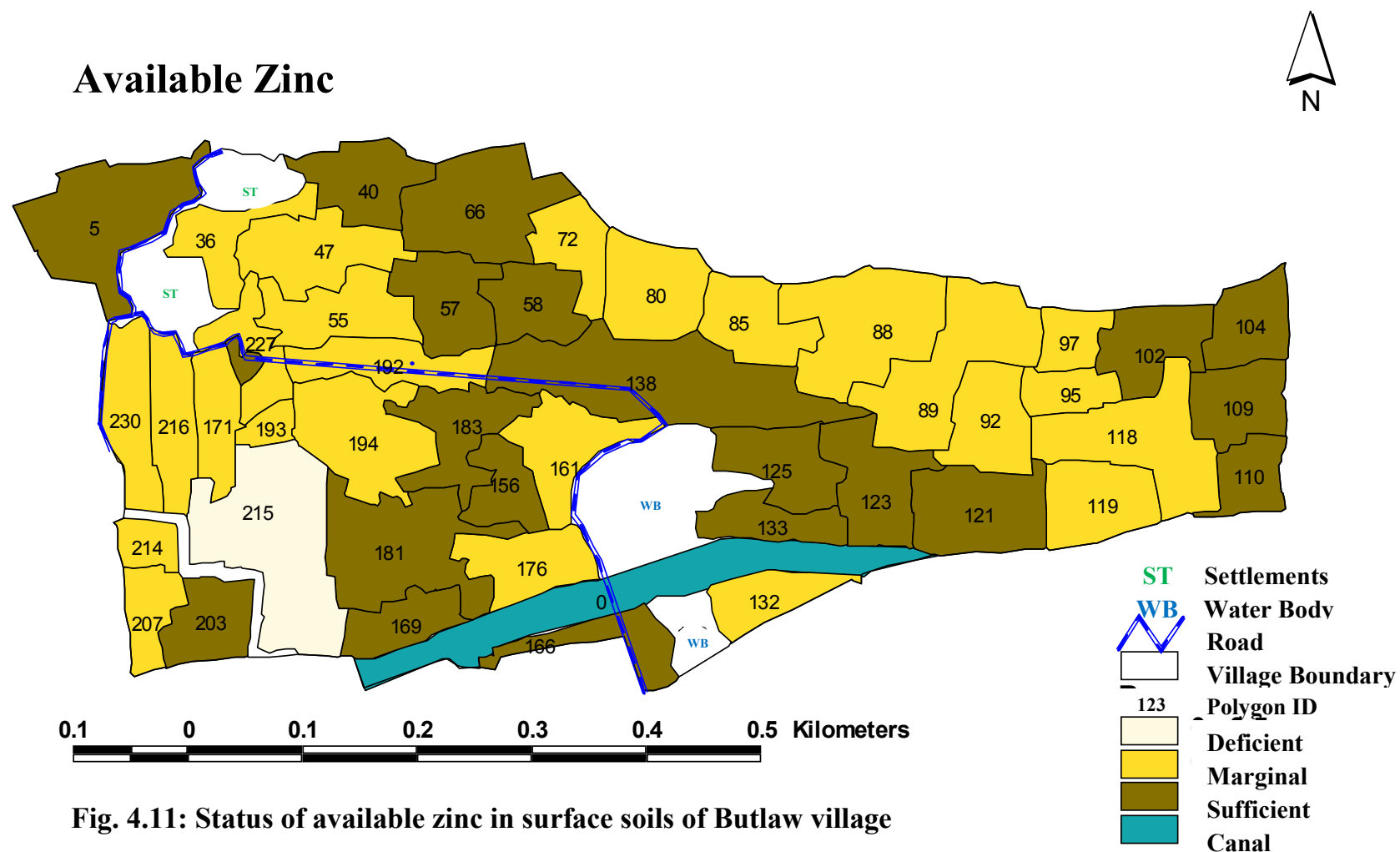
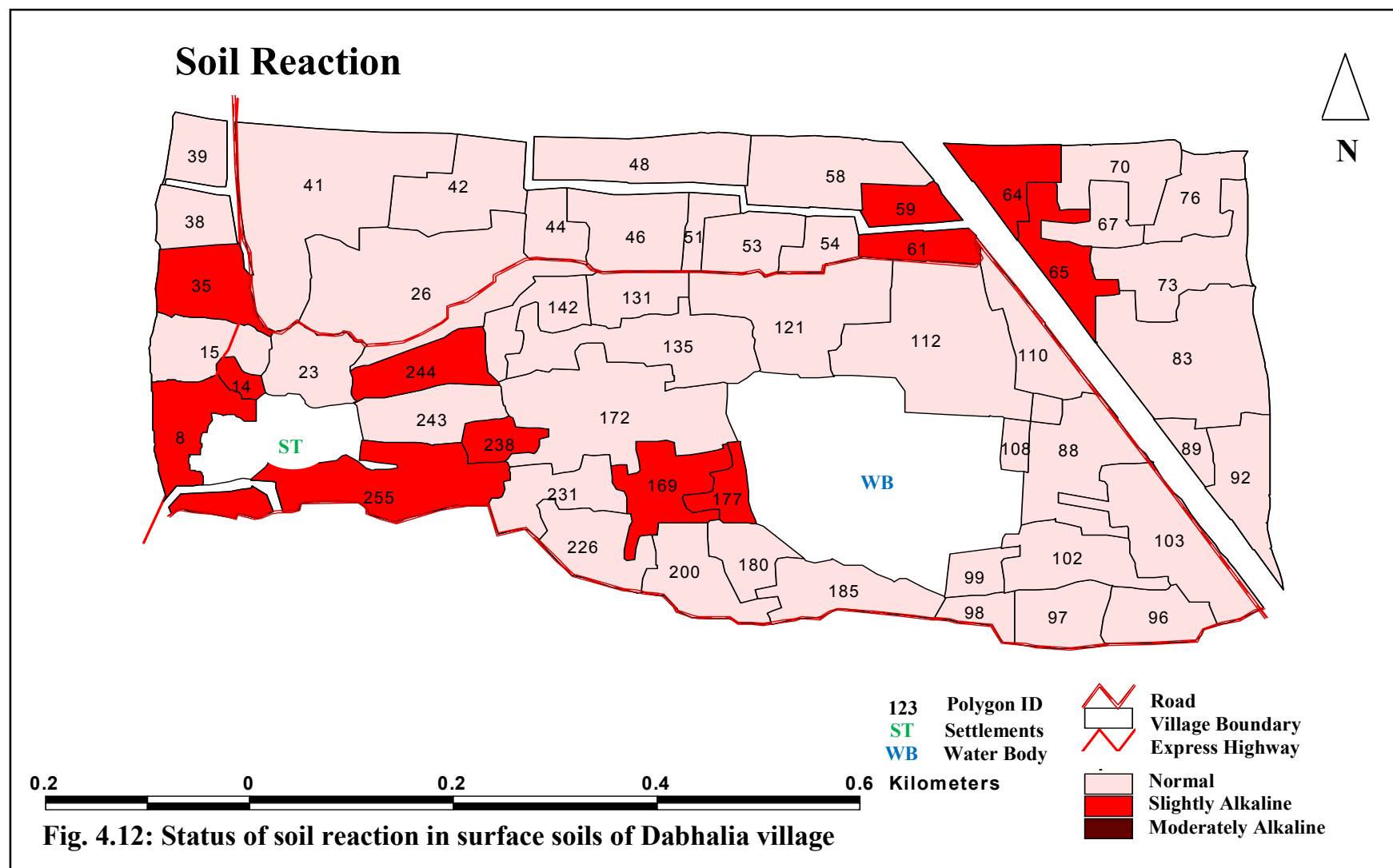
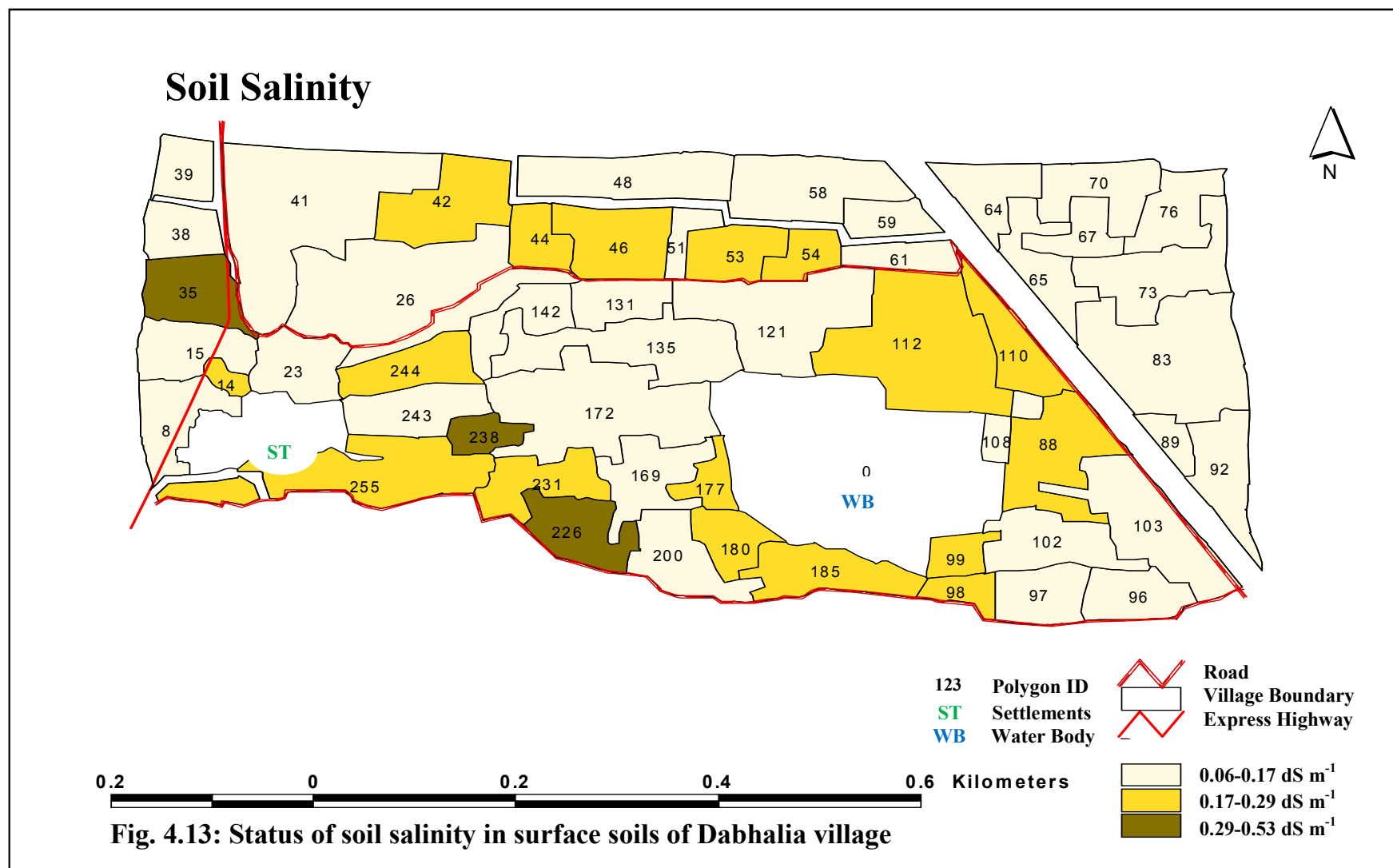


Fig. 4.11: Status of available zinc in surface soils of Butlaw village





Organic Carbon

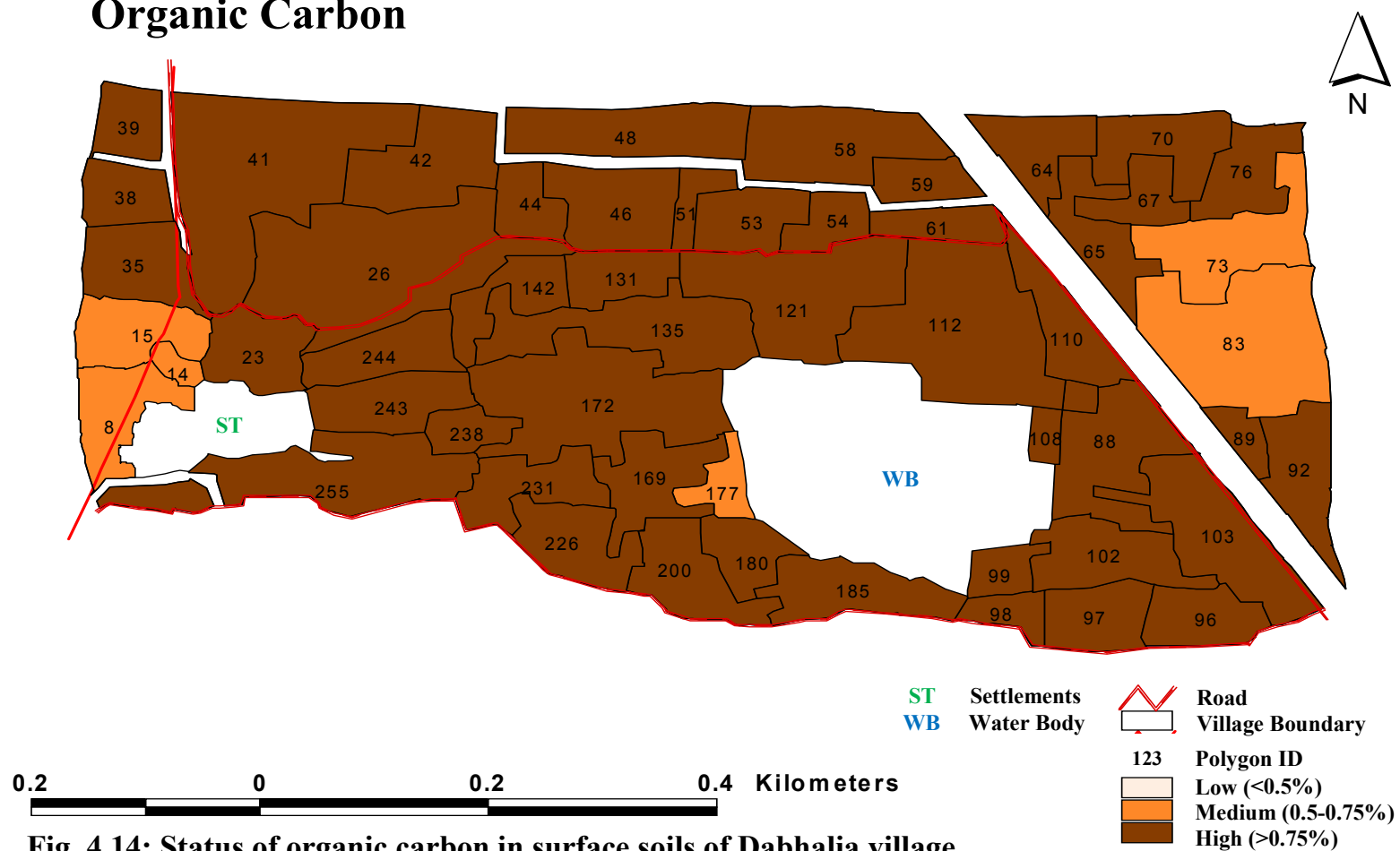
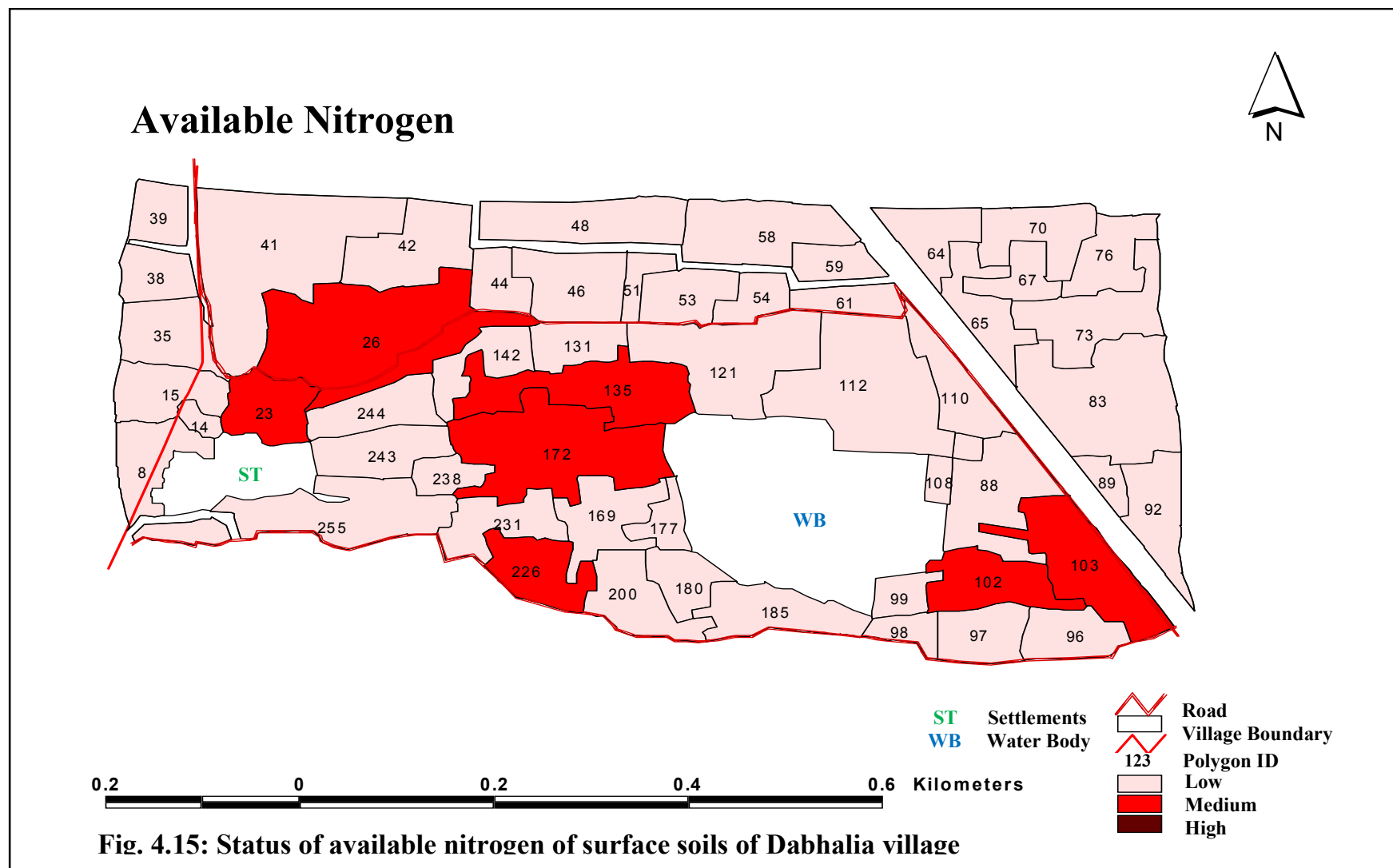


Fig. 4.14: Status of organic carbon in surface soils of Dabhalia village



Available Phosphorus

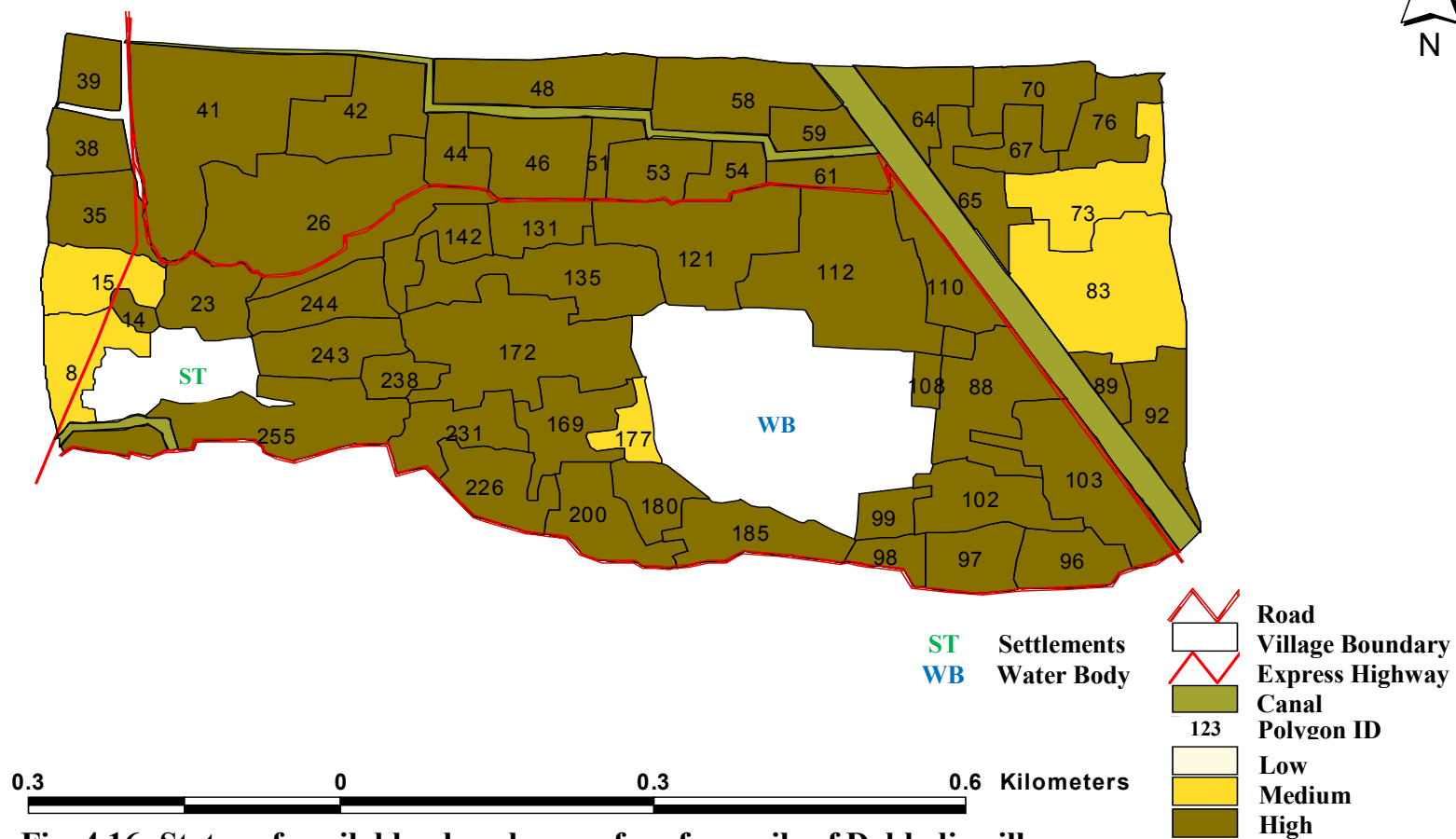


Fig. 4.16: Status of available phosphorus of surface soils of Dabhalia village

Available Potassium

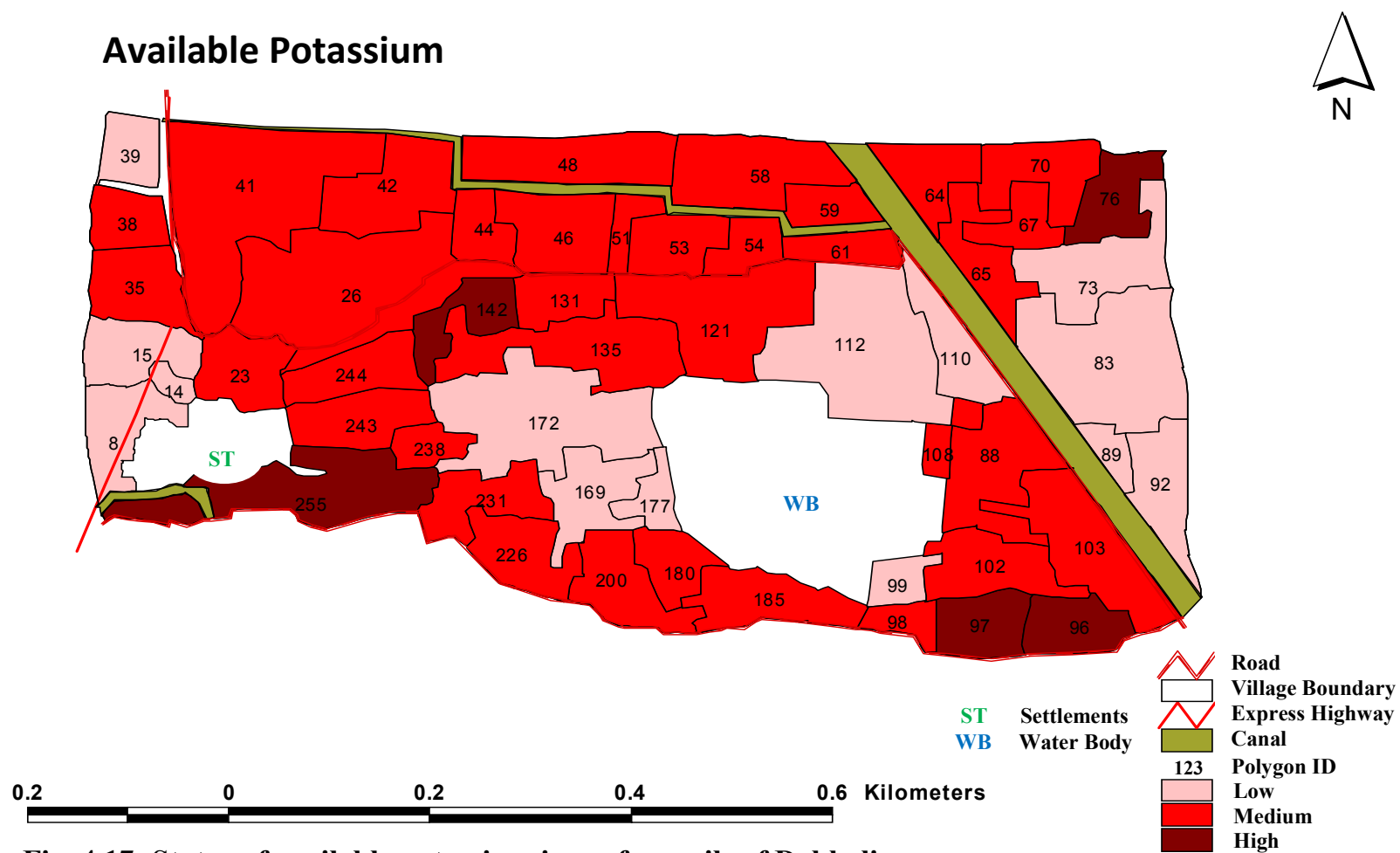
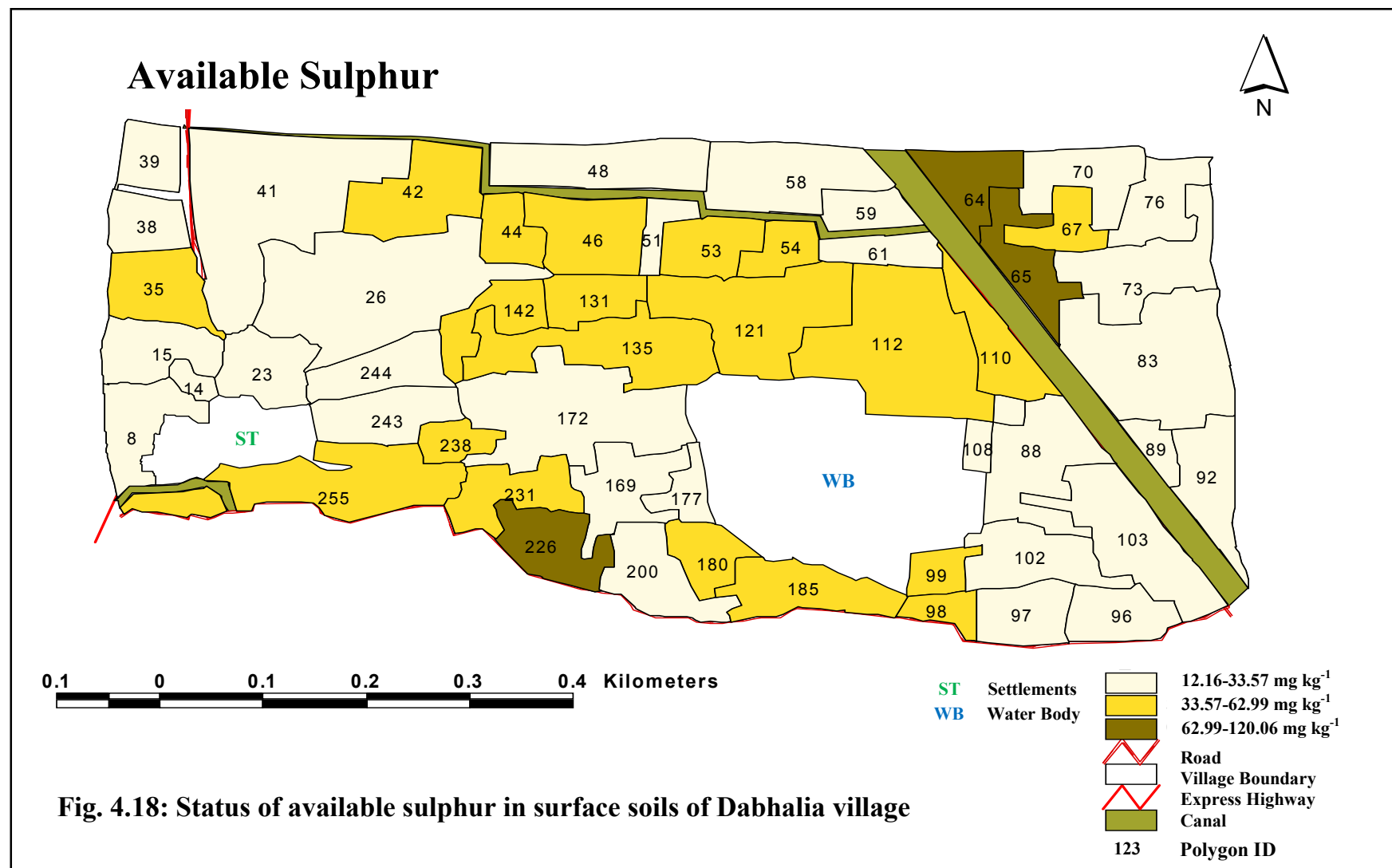


Fig. 4.17: Status of available potassium in surface soils of Dabhalia



Available Iron

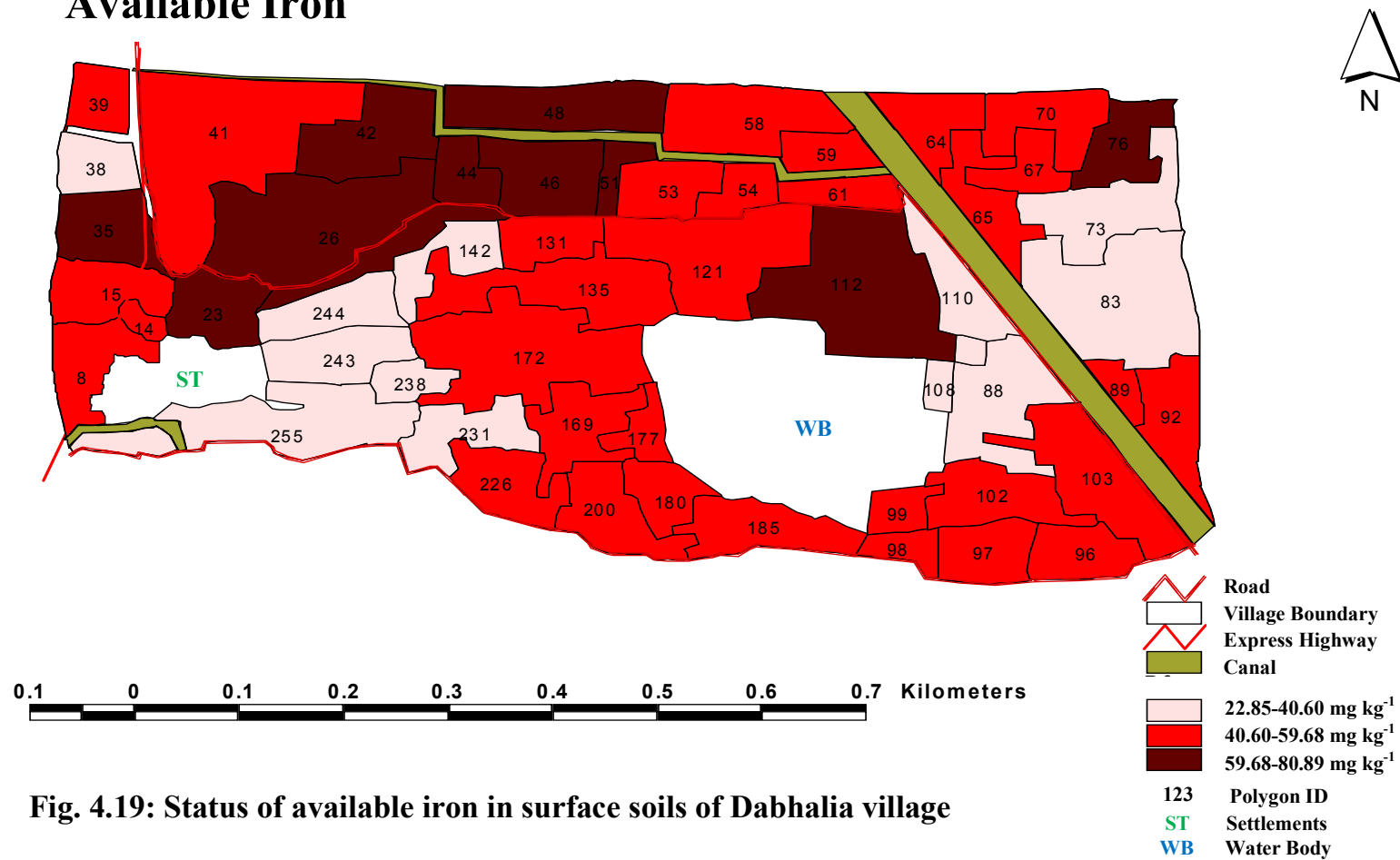


Fig. 4.19: Status of available iron in surface soils of Dabhalia village

Available Manganese

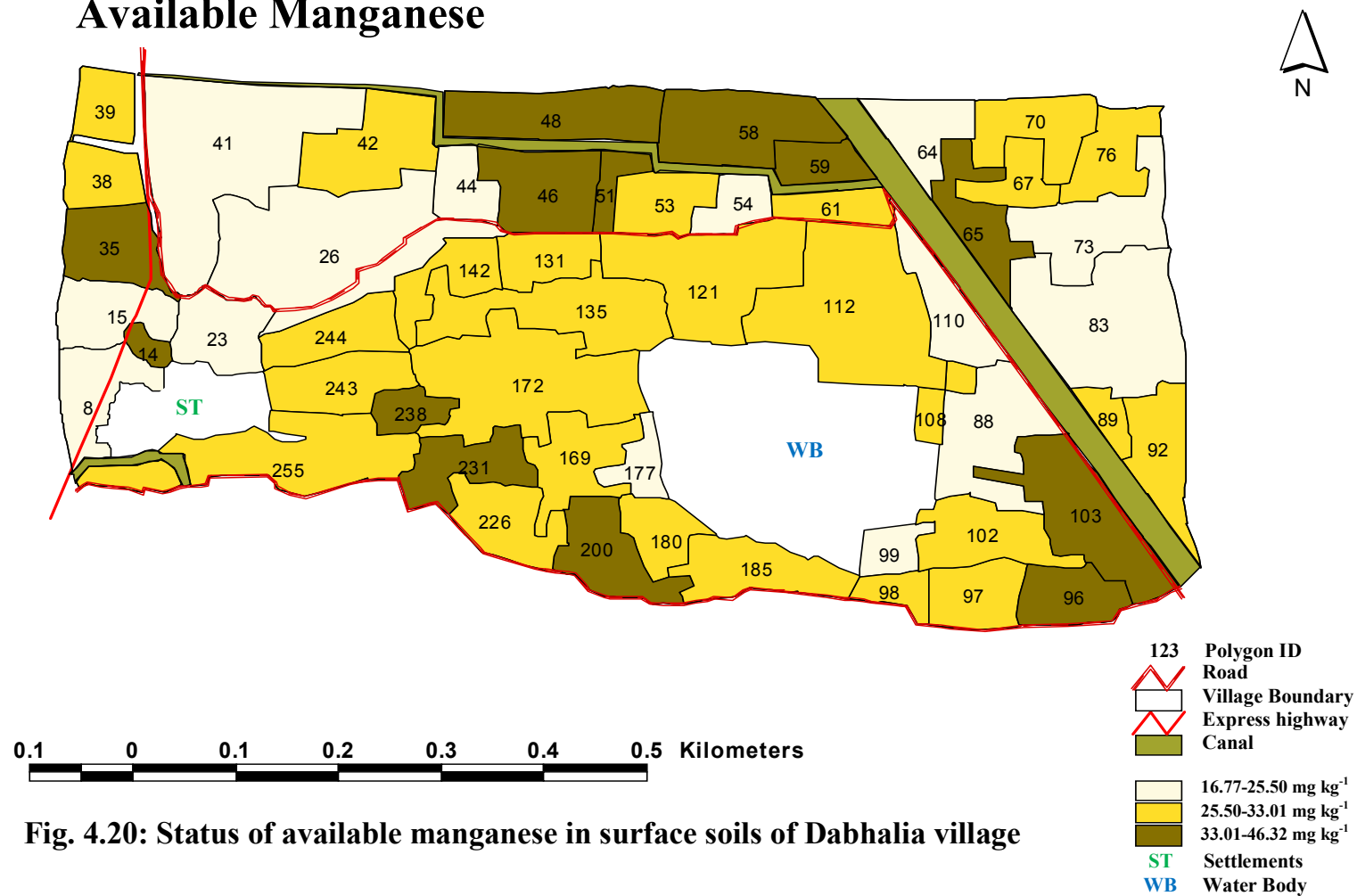


Fig. 4.20: Status of available manganese in surface soils of Dabhalia village

Available Copper

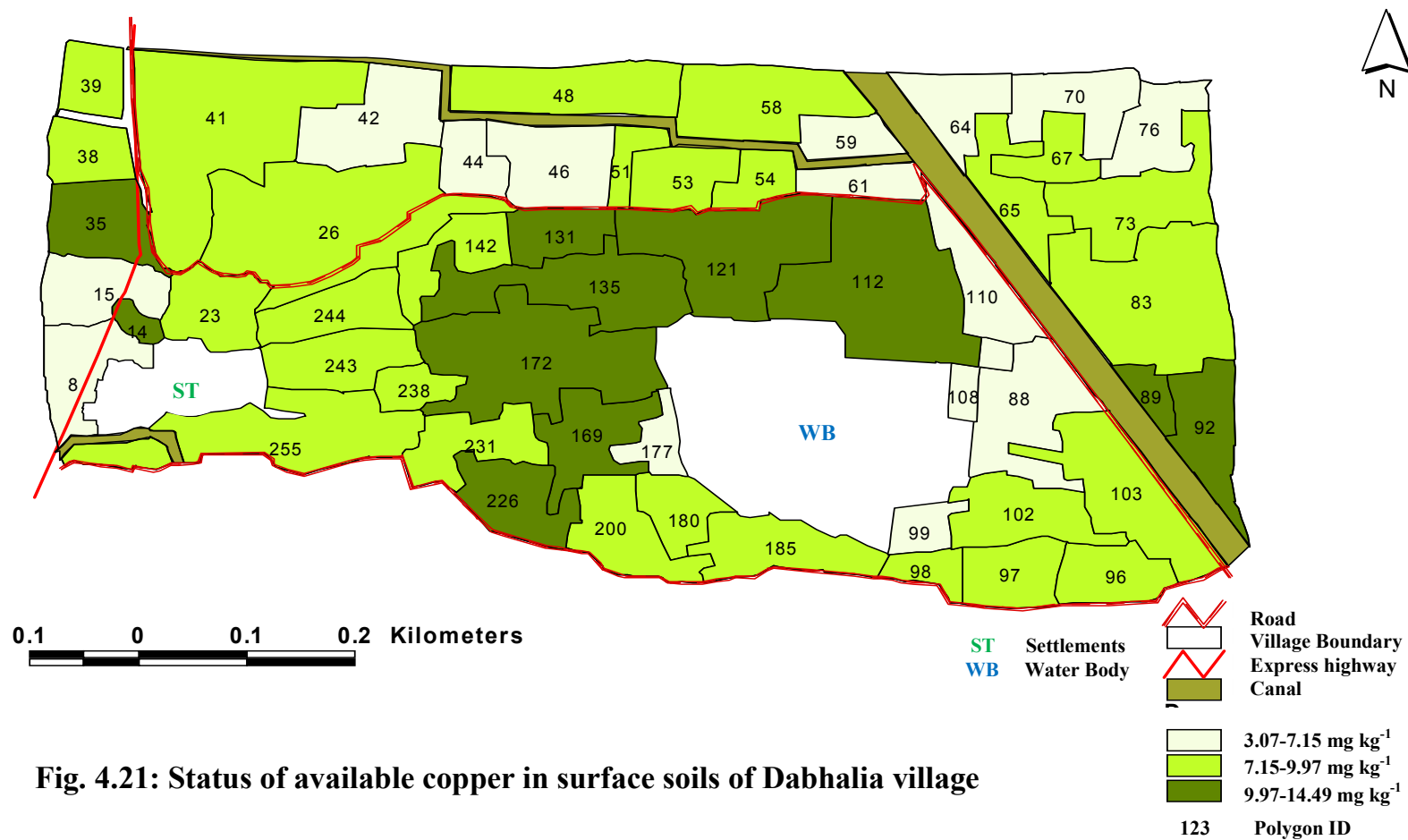


Fig. 4.21: Status of available copper in surface soils of Dabhalia village

Available Zinc

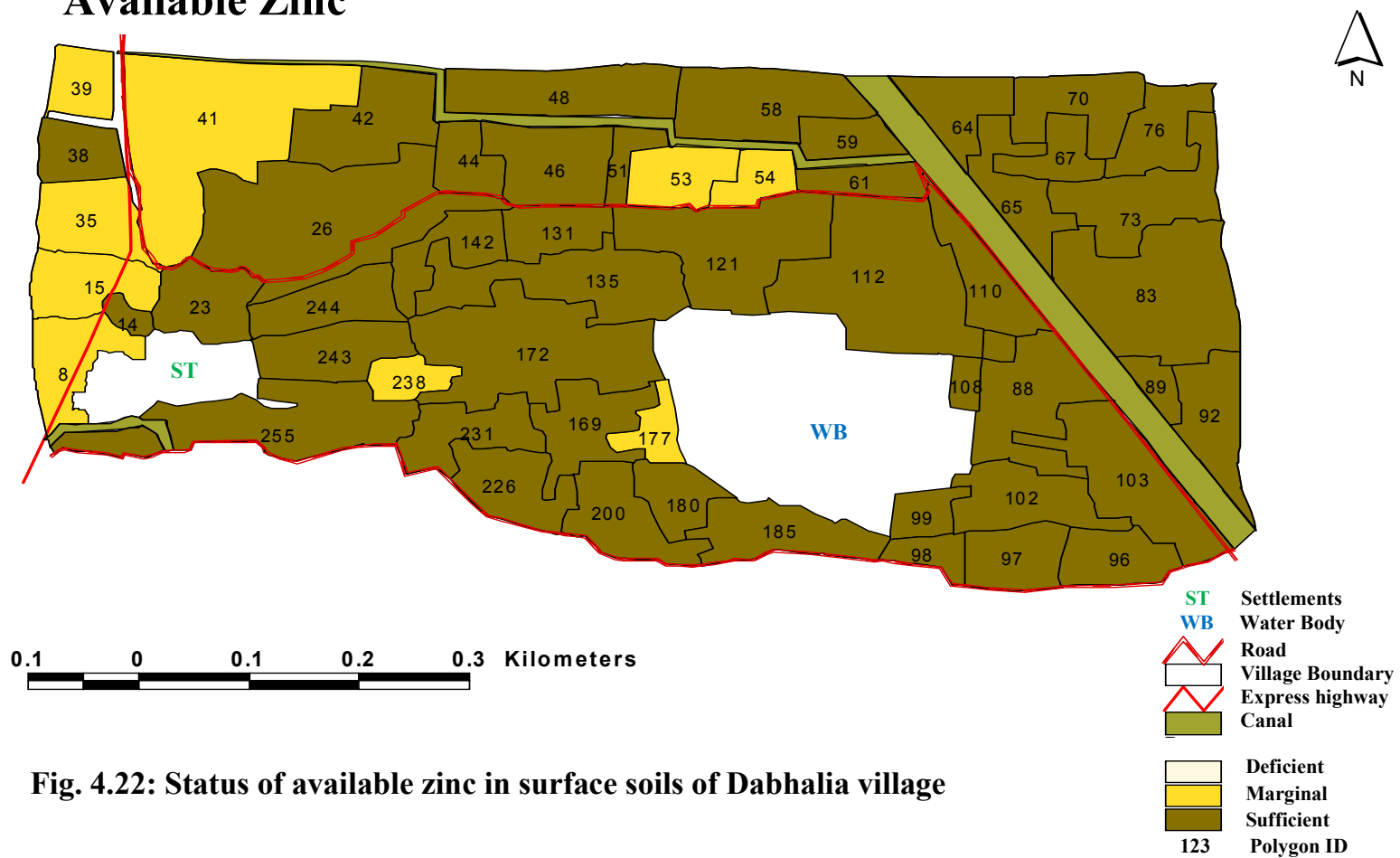


Fig. 4.22: Status of available zinc in surface soils of Dabhalia village

4.2 Climate

Like soil resource, for appropriate land use planning by evaluating soil-site suitability of various crops, characterization of climatic parameters is also essential. In order to characterize the climatic parameters *viz.*, rainfall, temperature, relative humidity, sunshine hours and wind velocity, daily data for past 30 years (1987 to 2016) were obtained from Department of Meteorology, N. M. College of Agriculture, NAU, Navsari. The parameter wise analysis is discussed here.

4.2.1 Rainfall

For effective land use planning, rainfall data are normally subjected to seasonal distribution, monthly distribution and deviation from annual average rainfall and rainfall at 75 per cent probability analysis considering the monthly mean data. For season wise distribution, whole year was divided in to four seasons *viz.*, cool weather precipitations (CWP) from January and February, hot weather precipitations (HWP) from March to May, south-west monsoon (SWM) from June to September and north-east monsoon (NWM) from October to December. The season wise distribution based on 30 years data depicted in the fig. 4.23 revealed that the selected study area receive about 97 per cent of rainfall during south-west monsoon within 45 to 55 rainy days and remaining 3 per cent precipitation is received during north-east monsoon season. As the majority of rainfall is received during south-west monsoon, the data were further processed and month wise distribution was worked out (Fig. 4.24). During the monsoon season, maximum rainfall (38.54 %) is received during July followed by August (21.22 %) and June (19.88 %). The average coefficient of variation is around 29.73 per cent which suggest that rainfall in this area is

relatively assured as compared to arid or semi arid regions of the state. The annual average rainfall was 1623 mm over the 30 years from 1987 to 2016. The year wise deviation of rainfall from the average value is presented in the fig. 4.25. Considering this variability, it was also thought to compute the rainfall probability at 75 per cent level which help in crop planning. Rainfall probability analysis was done and presented in the fig. No. 4.26, which shows that out of 30 years, 3 years received maximum rainfall of 2500 mm. During more than half of the years, rainfall was below average. Though, the selected area is enjoying canal irrigation facility, yet about 25 per cent area is left at the vagaries of weather. Ofcourse, even at 75 per cent probability level, this area receives about 1200 mm rainfall which is adequate for any *kharif* crops like lowland paddy, sorghum (fodder) *etc.* In the event of prolonged dry spell, one or two protective irrigations are required, which can be done through canal (if not) or bore well (where ever feasible).

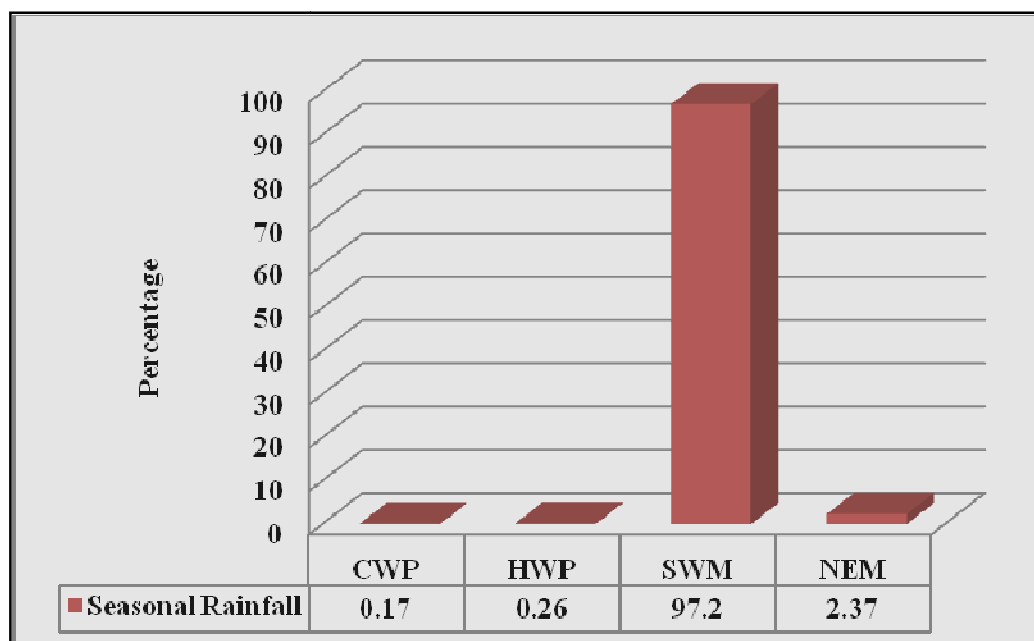


Fig. 4.23: Seasonal distribution of rainfall (1987-2016)

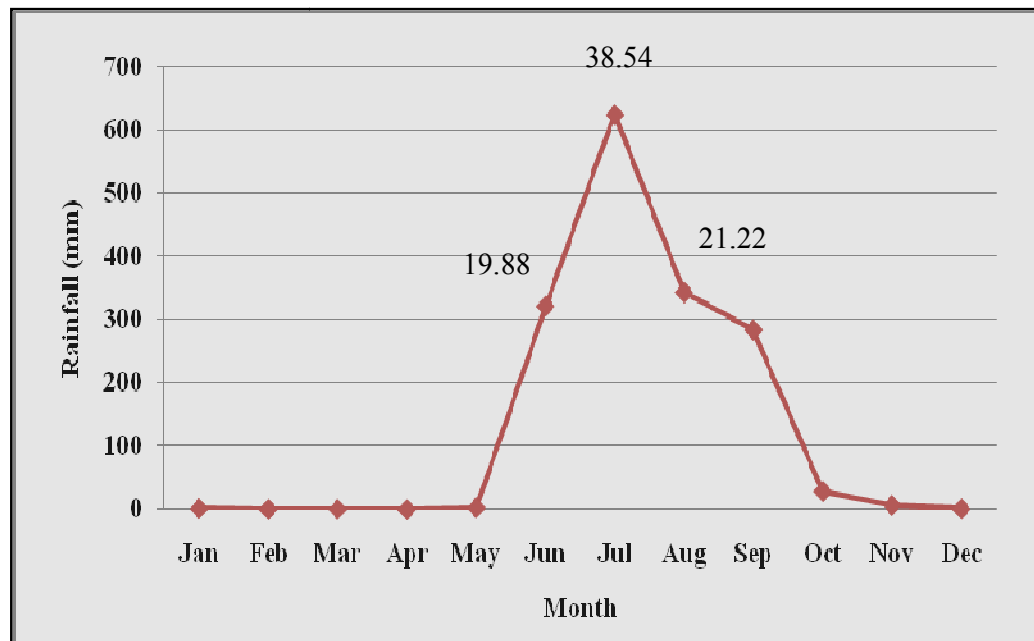


Fig. 4.24: Trend of south – west monsoon (mean monthly values 1987-2016)

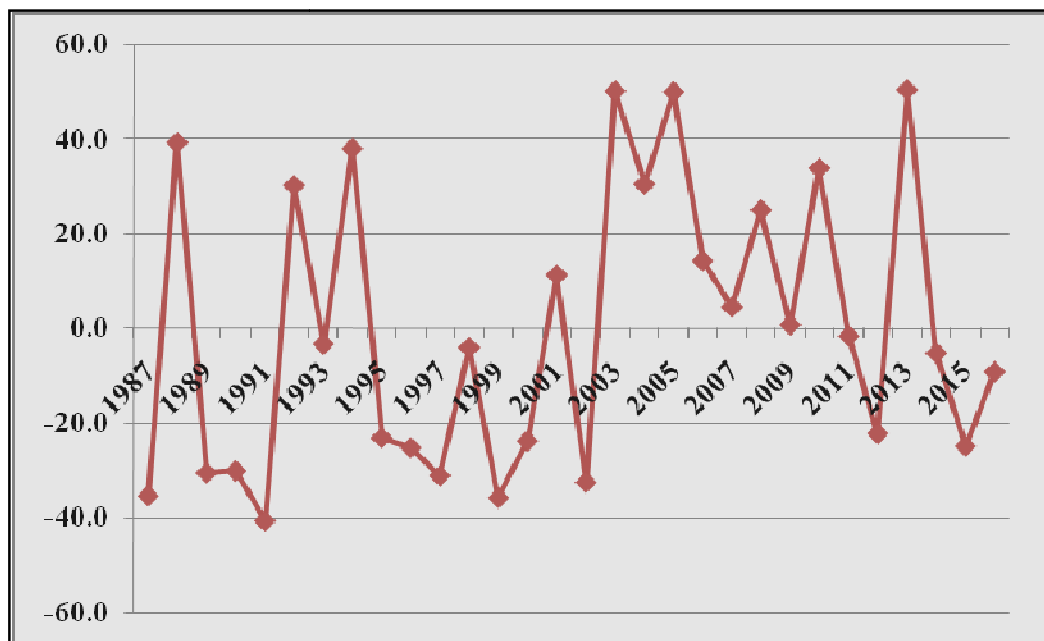


Fig. 4.25: Year wise deviation of rainfall from the average value (1987-2016)

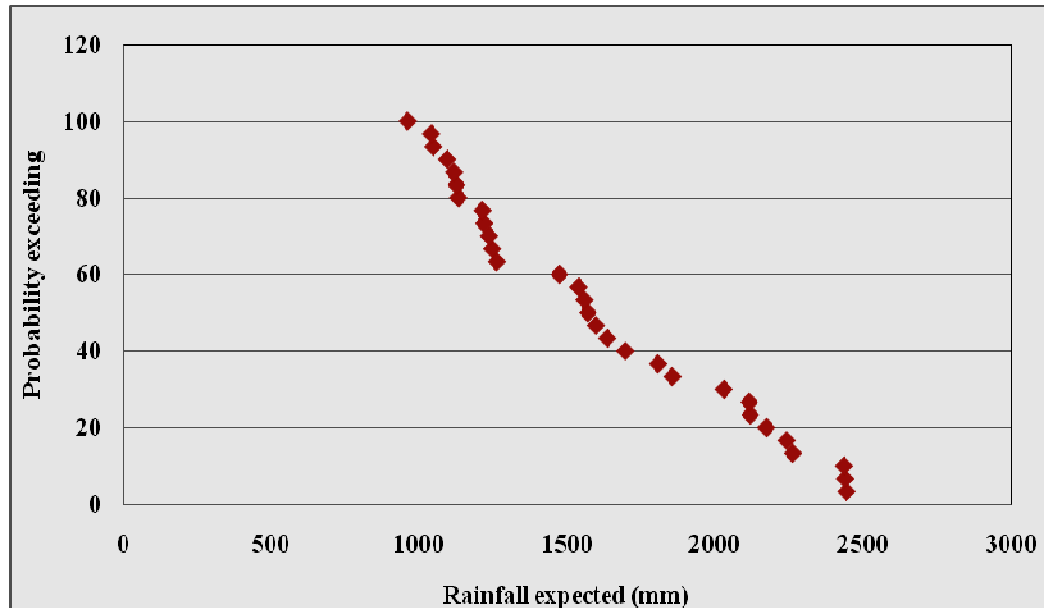


Fig. 4.26: Rainfall probability analysis (1987-2016)

4.2.2 Temperature

The mean monthly minimum temperature was ranging from 13.04 °C during January to 27.01 °C during June with an average of 21.16 °C. Similarly, the maximum temperature was varying between 29.30 °C during August and 35.20 °C in April with a mean value of 32.05 °C. The pattern of fluctuation in minimum and maximum temperature presented in fig. 4.27 revealed that the difference between minimum and maximum temperature was more during December to February and it tended to narrow down on either side of this period. This suggests the maritime influence on the temperature of the area. These data indicate prevalence of mild summer as well as winter in the selected study area.

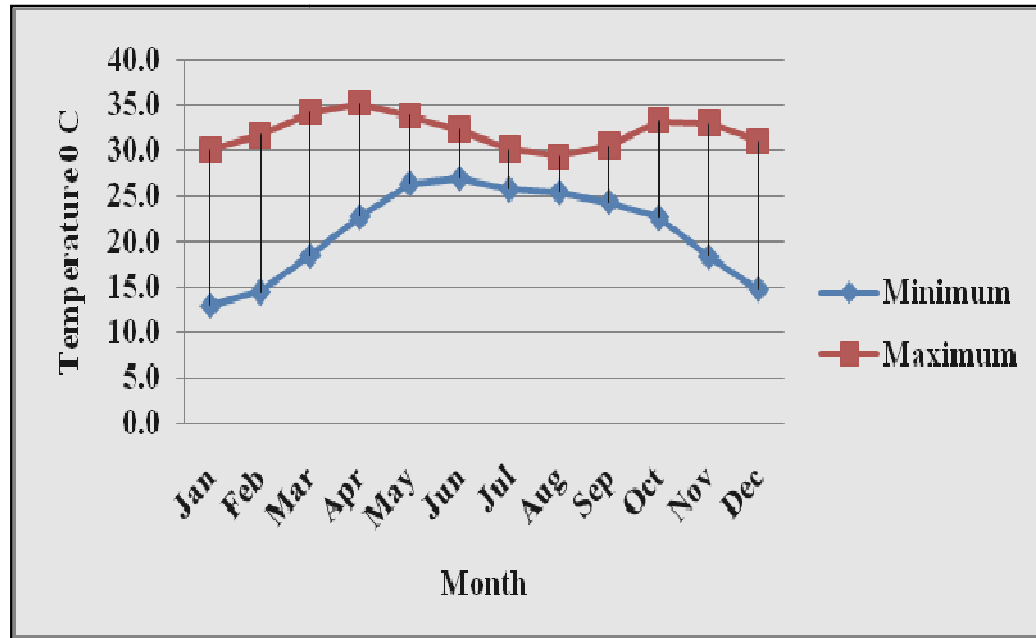


Fig. 4.27: Month wise fluctuation in minimum and maximum temperature (1987-2016)

4.2.3 Relative humidity (RH)

The month wise average values of RH recorded during morning and evening hours were computed using data from the year 1987 to 2016. The general trend of fluctuation in RH is presented in fig. 4.28. The RH recorded during morning hours was fluctuating between 78.34 per cent in February and 91.60 per cent in September. The corresponding values recorded during evening hours were 33.89 per cent during February and 81.07 per cent during July. In general, the gap between minimum and maximum RH is quite wider during November to April months and remains narrower during rest of the period.

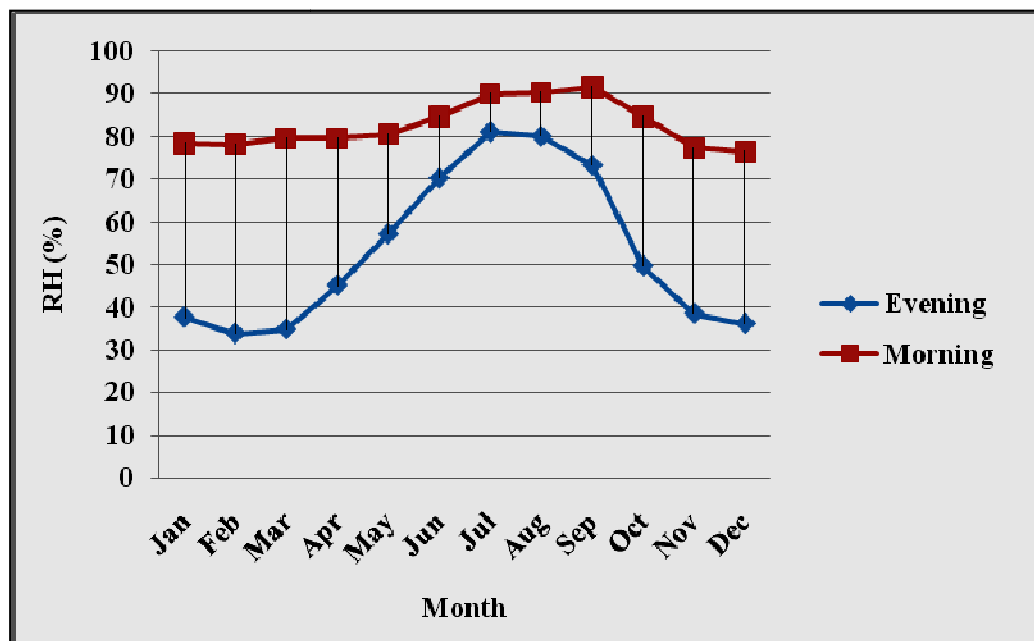


Fig. 4.28: Month wise fluctuation in morning and evening relative humidity (1987-2016)

4.2.4 Sunshine hours

The monthly average sunshine hours were computed using the data from 1987 to 2016 and depicted in fig. 4.29. The monthly mean value of sunshine hrs was varying between 3.26 hours in July to 9.99 hours in May with an annual mean of 7.80 hrs. The annual average sunshine period clearly indicate that it is sufficient to carry photosynthesis activities of most of the field and horticultural crops. Generally, the sunshine hours are much more during *rabi* and summer seasons *i.e.*, from October to May than monsoon season *i.e.*, from June to September. Though, most of the rainfall is received during June to September, the cloudy weather during this period resulted relative low sunshine hours.

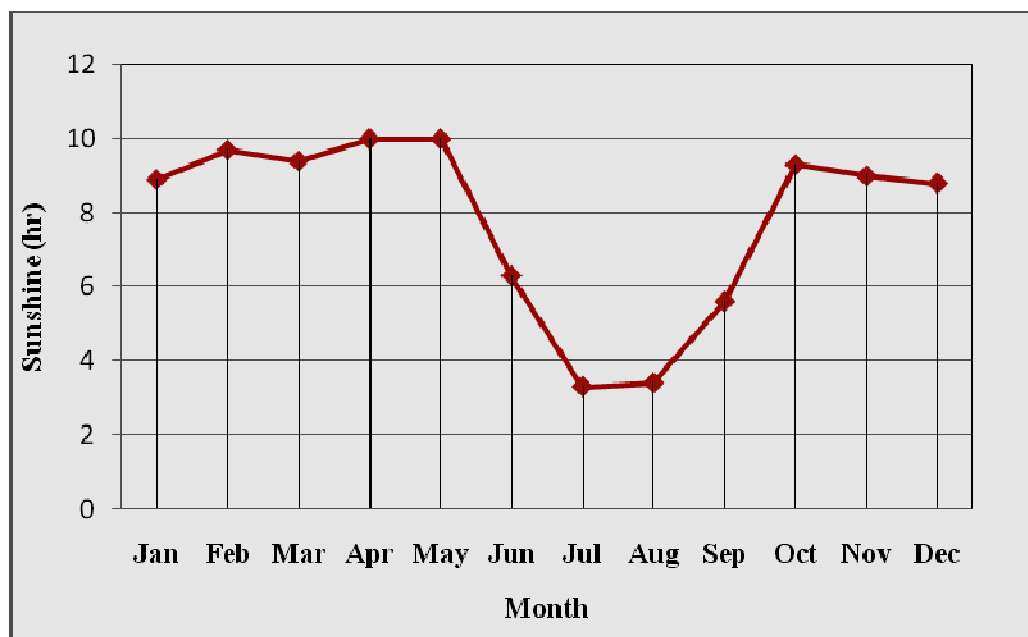


Fig. 4.29: Month wise fluctuation in sun shine hours (1987-2016)

4.2.5 Wind velocity

In spite of the location of the study area in coastal ecosystem, the annual average wind velocity is comparatively low (5.09 km hr^{-1}). It is ranging from 2.56 km hr^{-1} during October to 9.09 km hr^{-1} during June (Fig. 4.30). However, it is our experience that once or twice particularly prior to onset of monsoon, the area is subjected to cyclone and high tide events. Such events normally cause huge losses of *kharif* crops owing to inundation of sea water in low lying cultivated fields.

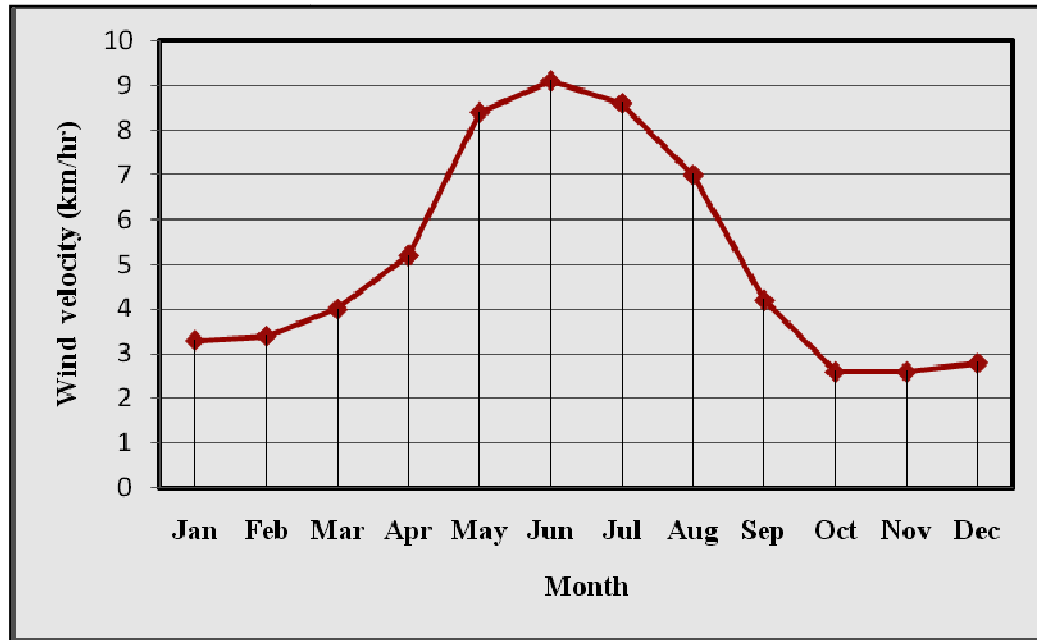


Fig. 4.30: Month wise fluctuation in wind velocity (1986-2016)

4.2.6 Hydrograph and length of growing period (LGP)

For the better understanding of climatic effect on crop production, interpretation of pertinent parameters in an integrated manner is an essential. For this purpose, potential evaporation (PE) values were obtained from temperature data using Blaney and Criddle procedure. Considering the precipitation (P) and PE, hydrograph was developed (Fig. 4.31). The hydrograph clearly indicate that during all the monsoon season P is invariably more than PE. This implies that during monsoon season excess water conditions prevails in the study area. The presence of excess water coupled with heavy textured soil causes water stagnation/water logging conditions during monsoon season which in turn restrict the crop selection during *kharif* to only the crops which can tolerate water logging/stagnation. In other words, we have to restrict our choice to crop like transplanted paddy particularly under low land condition.

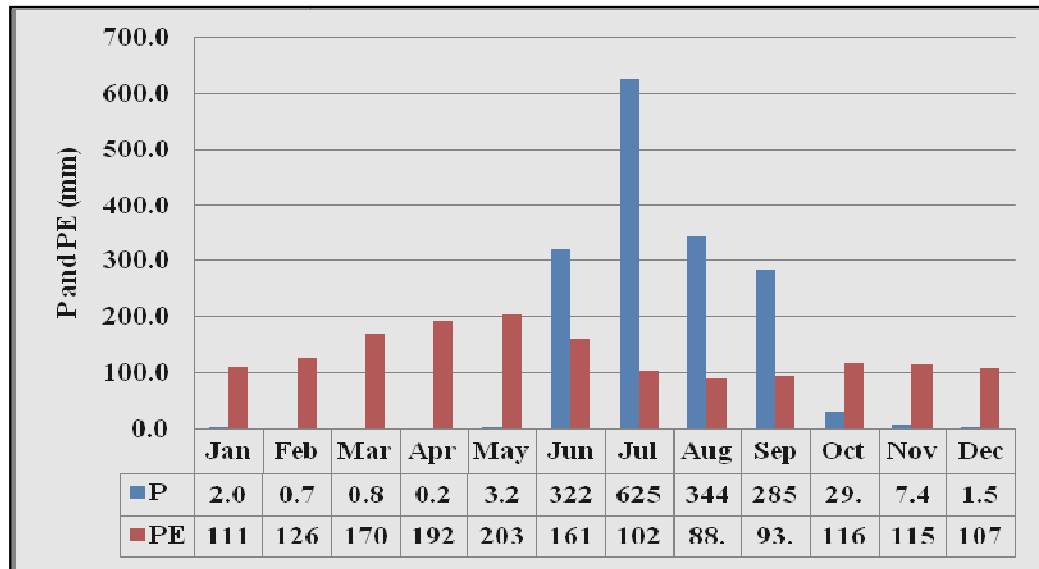


Fig. 4.31: Hydrograph of selected study area

The length of growing period (LGP) or the moisture availability period is a key parameter which helps in assessing climatic suitability to attain maturity within available LGP. In present study, the simple model developed by the Higgins and Kassam (1981) and FAO (1983) was used to estimate the LGP. The LGP of moisture availability period for crop growth, is the period (in days) when precipitation (P) exceeds 50 per cent of the PE plus the time required to evapo-transpire an assumed 100 mm of water from the stored moisture in the soil profile. During a normal growing season, crop experiences a humid or wet period (when $P > PET$), a moist period (when $P > 0.5 PET$) and moderately dry to dry period (when $P < 0.5 PET$). In this context, in selected study area LGP begins in the month of May *i.e.*, std. week 21 ($P > 0.5 PE$) and it ends in the last week of September (Fig. 4.32). In between this, moist and wet periods prevails during the months of June, July, August and first half of September, which work out to about 130 days of growing period. As such this period is good enough to support the growth of *khaif* crops which normally require

around 4 months for maturity. So, in the selected study area, *kharif* crops can be grown without any irrigation except 10-15 days dry spell where protective irrigation may be required. However, in view the heavy texture of the soils having poor permeability causes temporary water logging conditions which needs to consider while selecting the crops. The problem of water logging is of more serious nature in low lying areas.

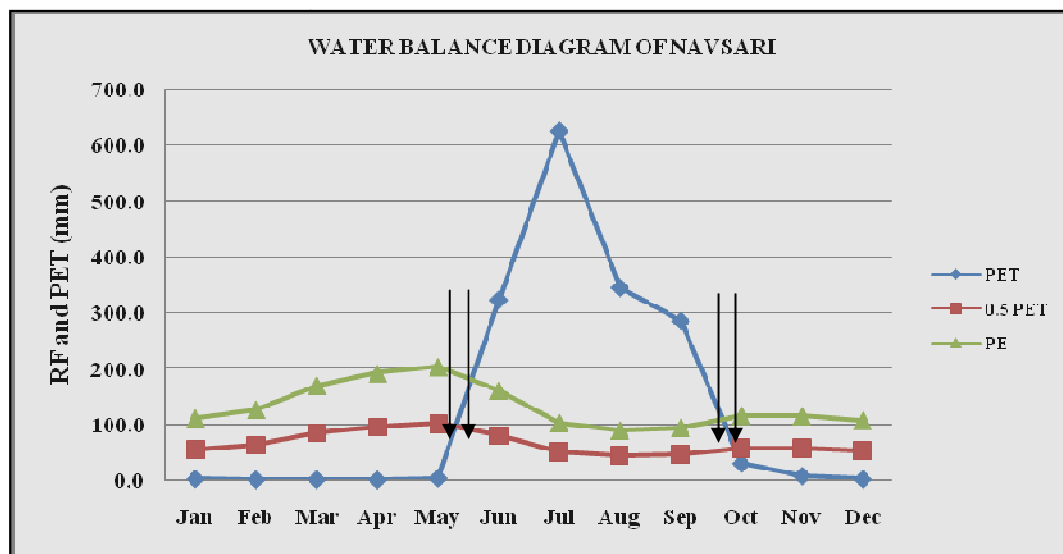


Fig 4.32: Length of growing period in selected study area (1987-2016)

4.3 Water resources

As discussed earlier, the study area is categorized as sub humid and receiving about 1623 mm rainfall. In addition, this area is endowed with canal irrigation facilities along with good ground water potential. A brief account of these resources is given here.

4.3.1 Surface water

The selected study area is irrigated through Navsari branches of Kakrapar left bank canal. Of the total cultivated area (212 ha), 81 per cent is irrigated, of which canal irrigation contribute 75 per cent and rest through ground water.

4.3.2 Ground water

Though, the selected villages are endowed with canal irrigation facility, yet farmers are compelled to use ground water in some parts owing higher elevation of their fields than canal head. The farmers are also using ground water for irrigation in the event of prolonged dry spell particularly at critical growth stages of crop during monsoon season. Similarly, the farmers also practices combined use of canal and ground water during *rabi* and hot seasons. In view of this, it was thought to assess the quality of ground water from irrigation point of view. So, from the selected villages, in all 30 ground water samples were collected during pre monsoon and post monsoon seasons of 2016-17 and analyzed for quality parameters *viz.*, pH, EC, SAR and RSC (Tables 4.21 and 4.22).

The pH of the water samples in the pre monsoon season is varying between 7.25 and 7.81 with a mean value of 7.51. The mean value indicate that in study area 100 per cent samples are

alkaline in reaction. The pH of the water samples in the post monsoon season is varying between 7.17 and 7.61 with a mean value of 7.40. The mean value indicate that in study area 100 per cent GW samples are also alkaline in reaction.

From salinity point of view, EC of GW in the pre monsoon season was ranging from 0.84 to 1.31 dS m⁻¹ with a mean value of 1.02 dS m⁻¹. During post monsoon season the EC was ranging from 0.77 to 1.22 dS m⁻¹ with a mean value of 0.93 dS m⁻¹. These mean values suggest the presence of saline water in study area and the 100 per cent GW samples were classified in the C₃ class for both the pre and post monsoon season. The reason behind ground water salinity might be due to location of the study area near by coastal region.

Based on the content of soluble cations in the water samples, the index of sodicity hazard SAR and RSC were computed. In the case of pre monsoon season SAR was ranging from 2.25 to 5.71 with a mean value of 4.26. And in the case of post monsoon season SAR was ranging from 1.27 to 3.74 with a mean value of 2.59.

The pre monsoon RSC value of water samples was ranging from 0.05 to 2.23 with a mean of 0.98. The RSC of post monsoon water samples was ranging from -0.10 to 2.23 with a mean vale of 0.87.

Overall the results shown that in the post monsoon season pH, EC, SAR and RSC of the ground water is decreases (Fig. 4.33). Similar results were reported by Ghodke *et al.* (2016) in Chakur teshil of Latur district of Maharashtra. The reason behind might be the dilution of ground water during monsoon season. Considering

the sodicity and salinity hazards, the ground water samples are categorized in different suitability classes. All the water samples are having salinity hazard as they belongs to C₃ class. From RSC point of view, 19 samples are found suitable and 11 samples are found moderately suitable during pre monsoon season whereas, in the case of post monsoon season 21 samples are found suitable and 9 samples are found moderately suitable.

Due the presence of salinity hazard in the ground water, it will be better to use the surface water for the irrigation purpose. If there is less availability of surface water, irrigation with ground water should be done after ensuring well drainage facilities in the field. Otherwise, due to the clay texture of the soil accumulation of salt may occur in the field.

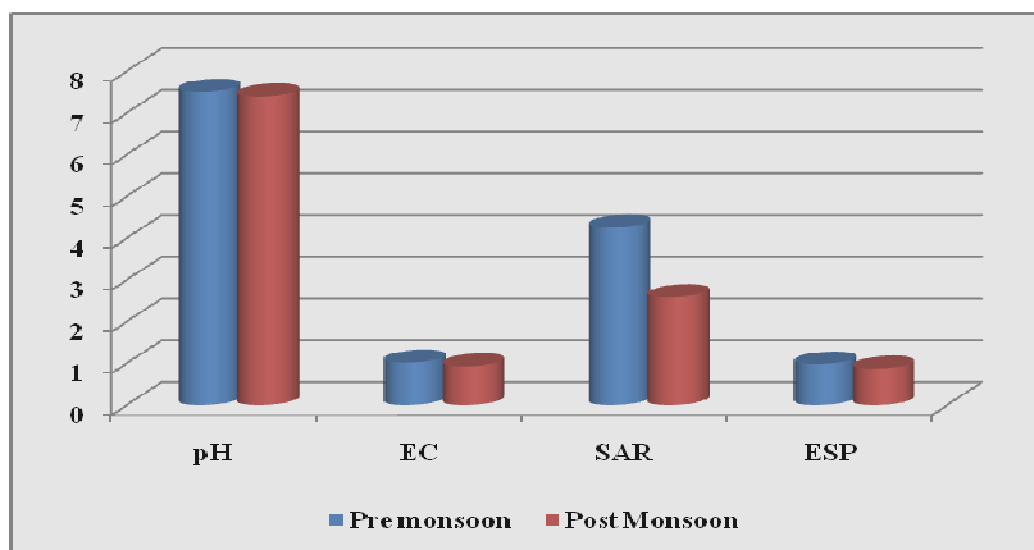


Fig. 4.33: Seasonal change in chemical properties of ground water

Table 4.21: Quality parameters and classification of ground water samples of pre monsoon season

Pre monsoon								
PN	Sample No	pH	EC (dS/m)	Class	SAR	Class	RSC (me ⁻¹)	Class
1	1	7.53	0.97	C ₃	2.67	S ₁	1.51	MS
	2	7.41	1.31	C ₃	2.96	S ₁	0.79	S
	3	7.63	0.96	C ₃	1.75	S ₁	0.34	S
	4	7.77	1.02	C ₃	3.82	S ₁	2.23	MS
	5	7.32	0.96	C ₃	2.23	S ₁	1.76	MS
	6	7.39	0.88	C ₃	1.39	S ₁	0.07	S
	7	7.35	0.88	C ₃	2.11	S ₁	0.97	S
	8	7.43	0.97	C ₃	2.69	S ₁	0.89	S
	9	7.26	1.13	C ₃	3.72	S ₁	1.83	MS
	10	7.25	1.07	C ₃	2.81	S ₁	1.09	S
	Min	7.25	0.88		2.25		0.07	
	Max	7.77	1.31		5.71		2.23	
	Mean	7.43	1.01		4.06		1.15	
2	1	7.63	0.99	C ₃	3.42	S ₁	1.61	MS
	2	7.42	1.22	C ₃	2.69	S ₁	0.73	S
	3	7.81	0.97	C ₃	2.13	S ₁	0.05	S
	4	7.59	0.99	C ₃	2.61	S ₁	0.52	S
	5	7.47	1.12	C ₃	2.57	S ₁	0.67	S
	6	7.51	0.92	C ₃	2.77	S ₁	0.63	S
	Min	7.42	0.92		3.40		0.05	
	Max	7.81	1.22		5.30		1.61	
	Mean	7.57	1.04		4.20		0.70	
3	1	7.36	0.97	C ₃	2.89	S ₁	1.71	MS
	2	7.42	0.95	C ₃	2.57	S ₁	1.42	MS
	3	7.51	0.91	C ₃	3.02	S ₁	1.58	MS
	4	7.46	1.01	C ₃	2.91	S ₁	0.39	S
	5	7.57	0.84	C ₃	3.01	S ₁	0.46	S
	6	7.62	1.31	C ₃	2.83	S ₁	0.61	S
	7	7.38	1.12	C ₃	3.41	S ₁	1.02	S
	8	7.61	1.21	C ₃	2.67	S ₁	1.45	MS
	9	7.62	0.98	C ₃	2.92	S ₁	1.17	S
	10	7.47	0.92	C ₃	3.11	S ₁	1.29	MS
	11	7.54	1.17	C ₃	2.61	S ₁	1.18	S
	12	7.57	0.91	C ₃	2.33	S ₁	0.67	S
	13	7.47	0.85	C ₃	3.27	S ₁	1.08	MS
	14	7.69	0.99	C ₃	3.18	S ₁	1.17	S
	Min	7.36	0.84		3.70		0.39	
	Max	7.69	1.31		5.30		1.71	
	Mean	7.52	1.01		4.51		1.09	
Overall	Min	7.25	0.84		2.25		0.05	
	Max	7.81	1.31		5.71		2.23	
	Mean	7.51	1.02		4.26		0.98	
C ₃ =High salinity hazard, S ₁ =Low sodium hazard, S=Suitable, MS=Moderately suitable								

Table 4.22: Quality parameters and classification of ground water samples of post monsoon season

Post monsoon								
PN	Sample No	pH	EC (dS/m)	Class	SAR	Class	RSC	Class
1	1	7.50	0.95	C ₃	2.65	S ₁	1.40	MS
	2	7.34	1.22	C ₃	2.83	S ₁	0.76	S
	3	7.54	0.95	C ₃	1.64	S ₁	0.25	S
	4	7.67	0.99	C ₃	3.74	S ₁	2.13	MS
	5	7.22	0.86	C ₃	2.11	S ₁	1.60	MS
	6	7.31	0.87	C ₃	1.27	S ₁	0.16	S
	7	7.25	0.87	C ₃	2.00	S ₁	0.90	S
	8	7.36	0.97	C ₃	2.52	S ₁	0.80	S
	9	7.19	1.03	C ₃	3.59	S ₁	1.70	MS
	10	7.17	0.95	C ₃	2.62	S ₁	1.00	S
	Min	7.17	0.86		1.27		0.06	
	Max	7.67	1.22		3.74		2.23	
	Mean	7.36	0.96		2.50		1.07	
2	1	7.52	0.88	C ₃	3.29	S ₁	1.50	MS
	2	7.36	1.12	C ₃	2.47	S ₁	0.60	S
	3	7.65	0.90	C ₃	1.98	S ₁	-0.10	S
	4	7.43	0.92	C ₃	2.40	S ₁	0.40	S
	5	7.35	0.97	C ₃	2.41	S ₁	0.50	S
	6	7.46	0.88	C ₃	2.67	S ₁	0.50	S
	Min	7.35	0.88		1.98		-0.10	
	Max	7.65	1.12		3.29		1.50	
	Mean	7.46	0.94		2.53		0.57	
3	1	7.29	0.86	C ₃	2.66	S ₁	1.50	MS
	2	7.26	0.83	C ₃	2.43	S ₁	1.30	MS
	3	7.34	0.79	C ₃	2.94	S ₁	1.50	MS
	4	7.31	0.93	C ₃	2.72	S ₁	0.30	S
	5	7.46	0.77	C ₃	2.88	S ₁	0.30	S
	6	7.42	1.20	C ₃	2.72	S ₁	0.50	S
	7	7.22	0.97	C ₃	3.29	S ₁	0.90	S
	8	7.53	1.03	C ₃	2.42	S ₁	1.30	MS
	9	7.48	0.85	C ₃	2.76	S ₁	1.00	S
	10	7.32	0.78	C ₃	2.88	S ₁	1.10	S
	11	7.36	0.91	C ₃	2.40	S ₁	1.10	S
	12	7.45	0.78	C ₃	2.19	S ₁	0.60	S
	13	7.38	0.79	C ₃	3.08	S ₁	1.00	S
	14	7.58	0.84	C ₃	3.03	S ₁	1.10	S
	Min	7.22	0.77		2.19		0.30	
	Max	7.58	1.20		3.29		1.50	
	Mean	7.39	0.88		2.74		0.96	
Overall	Min	7.17	0.77		1.27		-0.10	
	Max	7.67	1.22		3.74		2.23	
	Mean	7.40	0.93		2.59		0.87	

C₃=High salinity hazard, S₁=Low sodium hazard, S=Suitable, MS=Moderately suitable

4.4: Natural vegetation

In addition to cultivated crops, natural vegetation which includes trees and weed flora encountered during survey was also recorded and presented in tables 4.23 and 4.24 along with their botanical names and uses. Each and every species is having commercial value. Presence of such diversified tree species in the study area (Table 4.23), need to be explored for commercial purposes. Some of the fruit tree species like *ber*, *jamboo*, *Pithocolobim dulce* etc. can be exploited on large scale, as these trees are growing well in the study area.

Apart from tree species, weed flora was also recorded (Table 4.24). The presence of diversified weed flora in the study area indicate severe weed problem. This problem is accentuated further during monsoon due to existence of continuous wet condition. So, there is a need to take up weed control research on priority basis.

Table 4.23: Tree species of the selected study area

SN	Local Name	Botanical name	Uses
1	Khajuri	<i>Phoenix sylvestris</i>	Edible fruit, Niro preparation
2	Bangali babul	<i>Acacia auriculiformis</i>	Timber wood
3	Paras piplo	<i>Thespesia populnia</i>	Fodder and small wood
4	Deshibaval	<i>Acacia nilotica</i>	Fodder timber
5	Sevan	<i>Gmelina arborea</i>	Timber
6	Gorash ambli	<i>Pithocolobium dulce</i>	Edible fruit
7	Ashitro	<i>Bahunia recemosa</i>	Ceaves for bidi making, small timber, fuel

....Contd.

SN	Local Name	Botanical name	Uses
8	Sharu	<i>Casurina equisetifolia</i>	Timber
9	Bordi	<i>Zizyphus spp.</i>	Edible fruits, and fuel
10	Limdo	<i>Azadirachta indica</i>	Timber, medicinal and fodder
11	Dhedh umbro	<i>Ficus hispida</i>	Medicinal & fuel
12	Gundo	<i>Cordia alliodora</i>	Edible fruit, small timber
13	Lal Badam	<i>Terminalia catappa</i>	Edible fruit, small timber
14	Sag	<i>Tectona grandis</i>	Excellent timber
15	Neelgiri	<i>Eucalyptus tereticornis</i>	Timber, oil purpose
16	Shirish	<i>Albizia procera</i>	Timber , fodder
17	Umbro	<i>Ficus glomerata</i>	Medicinal & Fooder
18	Kher	<i>Acacia catechu</i>	Katha and Preparation
19	Kadu (Sand paper tree)	<i>Sterculia asper</i>	Fencing and fuel wood purpose
20	Simlo	<i>Bombax ceiba</i>	Medicinal, Small timber match splint, cotton
21	Naliari	<i>Coccoloba nucifera</i>	Edible fruit
22	Jamboo	<i>Syzygium cumini</i>	Edible fruit, medicin, timber
23	Khijdo	<i>Prosopis cineraria</i>	Fodder (Fruit & leaves), timber, fuel wood
24	Piludi	<i>Salvadora persica</i>	Oil preparation, soil conservation purpose
25	Arjun	<i>Terminalia arjuna</i>	Medicinal for heat diseases, timber
26	Sargvo	<i>Moringa oleifera</i>	Edible Fruits & Fuel wood Purpose

Table 4.24: Weed flora of the study area

SN	Weed	Botanical name	SN	Weed	Botanical name
1	Bhony ambli	<i>Phyllanthus mederashpatnesis</i>	15	Dhudhedi	<i>Euphorbia hirta</i>
2	Jal dudheli	<i>Oxystelma esculentum</i>	16	Jangli Bhindi	<i>Abelmoschus manihot</i>
3	Sahdevi	<i>Vernonia cynerea</i>	17	Satodi	<i>Boerhavia diffusa</i>
4	Khakhi	<i>Aeruvia spp.</i>	18	Nasotar	<i>Merremia turpenthun</i>
5	Aakhero	<i>Hygrophyla auriculata</i>	19	Baru	<i>Shorghum halepense</i>
6	-	<i>Stemodia viscosa</i>	20	Dhavlo	<i>Alysicarpus longifolia</i>
7	Kamboi	<i>Phyllanthus raticulata</i>	21	Chidho	<i>Cuprus rotundus</i>
8	Garni pipar	<i>Clitoric ternatea</i>	22	Undri	<i>Merremia gangetica</i>
9	Gorakh mumdi	<i>Sphareranthus indicus</i>	23	Kalar	<i>Blumea lacera</i>
10	Viklo	<i>Maytenus emarginata</i>	24	Khapat	<i>Abutilon indicum</i>
11	Chunchh	<i>Corchorus trilocularis</i>	25	Luni	<i>Suaeda fruticosa</i>
12	Kalo okhrat	<i>Chrozophora rottleria</i>	26	Dabhlo	<i>Desmostachya bipinnata</i>
13	-	<i>Gantelbua urens</i>	27	Samo	<i>Echinochloa crusgulli</i>
14	Krishan kamal	<i>Passiflora foetida</i>	28	Bhangro	<i>Eclipta prostrata</i>

4.5: Soil site suitability evaluation

Paddy and Sugarcane are the main crops of the selected study area, so the crop suitability evaluation was carried out. Profile 2 is evaluated as highly suitable (S_1), while profile 1 and 3 are evaluated as moderately suitable (S_2) for paddy crop cultivation. In relation to sugarcane crop profile 3, 2 and 1 are evaluated as highly suitable (S_1), moderately suitable (S_1) and marginally suitable (S_3) for cultivation, respectively.

Table 4.25: Soil-site suitability evaluation of paddy crop

Soil–site characteristics		P-1	P-2	P-3
Climate regime	Mean temperature in growing season	S2	S2	S2
	Total rainfall	S1	S1	S1
Oxygen availability to roots	Soil drainage	S3	S1	S3
	Free from flooding	S1	S1	S1
	Depth of water	N	N	N
Nutrient availability	pH	S3	S2	S3
	CEC	S1	S1	S1
	CaCO ₃ in root zone	S1	S1	S1
Rooting conditions	Effective soil depth	S1	S1	S1
Soil toxicity	Salinity (ECe)	S1	S1	S1
	Sodicity (ESP)	S1	S1	S1
Erosion hazard	Slope	S2	S1	S1
	Overall suitability	S2	S1	S2

Table 4.26: Soil-site suitability evaluation of Sugarcane crop

Soil-site characteristics		P-1	P-2	P-3
Climate regime	Mean temperature in growing season	S2	S2	S2
	Mean minimum temperature in growing season	S2	S2	S2
	Mean RH (%) in Growing season	S1	S1	S1
	Mean RH (%) in Ripening season	S2	S2	S2
Oxygen availability to roots	Soil drainage	S1	S3	S1
	Depth of water	S1	S2	S1
Nutrient availability	Texture	S3	S3	S2
	pH	S2	S2	S1
	CEC	S1	S1	S1
Rooting conditions	Effective soil depth	S1	S1	S1
	Stoniness	S1	S1	S1
Soil toxicity	Salinity (ECe)	S1	S1	S1
	Sodicity (ESP)	S1	S1	S1
Erosion hazard	Slope	S1	S1	S1
	Overall suitability	S2	S3	S1

SUMMARY AND CONCLUSION



V. SUMMARY AND CONCLUSION

The present investigation was carried out with an objective of soil fertility evaluation of the village Butlaw and Dabhalia in Navsari district of Gujarat, where characterization of natural resources *viz.* soil, climate, water and vegetation. Land use was recorded and crop suitability evaluation was done. Three representative profiles were excavated in the study area based on the land use and topography. Profiles were studied, interpreted and then sampled horizon-wise as per standard procedure (Soil Survey Staff, 2006). From the each representative profile area, grid point based surface (0-20cm) and sub-surface (20-40cm) soil sampling was done from hundred and two locations with the help of GPS. All surface, sub-surface as well as profile samples were analyzed for physical and chemical properties to fulfil the objectives. In order to characterize the climatic parameters *viz.*, rainfall, temperature, relative humidity, sunshine hours and wind velocity, daily data for past 30 years (1987 to 2016) were collected from Department of Meteorology, N. M. College of Agriculture, NAU, Navsari and parameter wise analysis was done. Ground water was collected analysed in the pre monsoon as well as post monsoon season. Natural vegetation which includes tree and weed flora was identified and present land use patterns also recorded. Soil-site suitability of the most common crops of the area *i.e.*, paddy and sugarcane was carried out. The survey data and interpretation discussed in the preceding chapters are summarized below.

5.1 Summary

5.1.1 Soil

- Taxonomically the soils of study are classified as *Typic Haplusterts* (Profile 1 and 2) and *Typic Haplustepts* (Profile 3).
- In profile area 2, there is drainage and permeability problem owing to high mean clay content (66.90%). While in the case of profile 1 and 3 areas, the problem of drainage does not exist due to less clay content.
- Surface soils of the study area are normal to slightly alkaline in nature. From the salinity point of view the surface soils of the study area are non-saline in nature. There is no sodicity problem in the study area. Soils are having good CEC due to their clayey nature.
- From Nutrient index point of view, soils fertility status of surface soils are high for OC, available P_2O_5 , K_2O , S, Fe, Mn, and Cu in the entire study area. The available N content was found low, medium and high in the profile area 2,1 and 3, respectively. In the case of available Zn, it was recorded medium in the profile area 3 but high in both the profile 1 and 2 area.

5.1.2 Climate

- Climate of the selected study area is sub humid and receiving about 1623 mm rainfall in 50 rainy days. Highest rainfall was observed in July followed by August and June. South-West monsoon was reported to contribute about 97 percent of the total rainfall.

- Lowest mean monthly minimum temperature was observed in January and the highest mean monthly minimum temperature was observed in June. Lowest mean monthly maximum temperature was observed in August and the highest mean monthly maximum temperature was observed in April.
- Relative humidity was high due to maritime effect which causes pest and disease problems. Highest relative humidity was observed in the month of August-September and lowest humidity was in the month of February-March.
- The monthly mean value of sunshine hours varying between 3.26 hours in July to 9.99 hours in April with an annual mean of 7.80 hrs.
- Wind velocity ranging from 2.56 km hr⁻¹ during November to 9.09 km hr⁻¹ during June with the annual average wind velocity of 5.1 km hr⁻¹.

5.1.3 Water

- During the pre monsoon season the pH of GW ranging from 7.25 to 7.81 with a mean of 7.51 while pH of GW decreases in the post monsoon season and it was ranging from 7.17 to 7.67 with a mean of 7.40. All the water samples of the study area were observed to be alkaline in nature.
- During the pre monsoon season the EC of GW were recorded ranging from 0.84 dS m⁻¹ to 1.31 dS m⁻¹ with a mean of 1.02 dS m⁻¹. Whereas during post monsoon season it ranged from 0.77 dS m⁻¹ to 1.22 dS m⁻¹ with a mean of 0.93 dS m⁻¹. The ground water samples of the study area were reported to have high salinity hazard.

- From the SAR point of view, all the water samples were recorded as non sodic in nature. Decrease in SAR value of the ground water samples was reported during post monsoon season.
- The RSC of ground water samples were recorded ranging from 0.05 to 2.23 me l⁻¹ with a mean of 0.98 me l⁻¹ during pre monsoon season. During post monsoon it was found ranging from -0.10 to 2.13 me l⁻¹ with a mean of 0.87 me l⁻¹ and all the water samples were classified within suitable to moderately suitable class from the RSC point of view.

5.1.4 Vegetation

- Abundant natural vegetation observed in the study area and *phoenix sylvestris*, *Acacia nilotica*, etc., are of common occurrence.
- Diversified weed flora was observed in the whole study area. They cause considerable losses in crop production.

5.1.5 Land use

- Paddy (49 %), Sugarcane (34 %), Spider Lili (17%) and Mango and Sapota (10%) are the predominant crops grown in the selected study area.
- Paddy and Spider lili cultivation was found relatively more in the low land conditions. Sugarcane crop was found equally distributed throughout the study area. Horticultural crops were grown in the relatively high elevated area near by the settlements.

5.1.6 Crop suitability

- Profile No. 2 representing the western part of Dabhalia village in the vicinity of Navsari branch of Ukai Kakarapar Command (UKC) was found more suitable for paddy than the others existing crops.
- Sugarcane crop was found more suitable in the Profile area 1 and 3.

5.2 Conclusions

Based on the results of present study following conclusions are emerged.

- ✓ Nutrient management of nitrogen and zinc is most important in the study area, as others nutrient are sufficiently present.
- ✓ Proper drainage management should be follow as there are so many lands are situated in the low land condition from where more salt accumulation was detected.
- ✓ Irrigation should be done with surface water wherever it is available because ground water having salinity hazard. As the texture of the study area soil is clay, soil salinity may develop due to prolong irrigation practice with GW.
- ✓ Growing of paddy crop in the profile area 2 is more advisable, while growing of sugarcane in the profile area 3 is more advisable.
- ✓ The thematic maps generated from this study can be used for recommending fertilizer doses for optimising nutrient use efficiency.

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APPENDICES



APPENDICES

Appendix I: Chemical properties of surface and sub-surface soils of profile area 1 (Western Butlaw village)

Polygon ID No.	0-20cm soil				20-40cm soil			
	pH	EC	CEC	ESP	pH	EC	CEC	ESP
	(1:2.5)		(cmol (p ⁺) kg ⁻¹)	%	(1:2.5)		(cmol (p ⁺) kg ⁻¹)	%
5	7.30	0.18	36.96	1.80	7.80	0.17	46.47	1.60
36	8.12	0.29	40.75	6.45	8.60	0.25	50.52	7.37
40	7.35	0.14	33.75	1.58	8.39	0.13	39.13	1.57
47	7.99	0.19	36.06	2.65	8.35	0.17	45.00	2.94
55	7.95	0.27	47.58	1.26	8.46	0.27	56.86	2.31
57	7.29	0.13	34.73	1.68	8.17	0.12	40.25	1.65
58	7.94	0.29	39.34	2.46	8.13	0.22	42.34	2.35
66	7.48	0.14	34.75	1.62	8.70	0.15	41.31	1.69
72	7.32	0.46	40.90	2.31	8.38	0.21	46.04	3.20
80	7.85	0.28	37.95	2.58	8.11	0.22	41.56	2.54
138	7.78	0.26	36.88	2.54	8.02	0.21	40.46	2.59
156	7.05	0.14	37.31	1.23	7.69	0.13	48.18	1.30
161	7.52	0.19	37.80	2.05	8.36	0.15	46.38	1.83
169	6.98	0.20	40.43	1.21	7.81	0.14	43.90	1.07
171	7.25	0.16	38.33	1.13	7.87	0.14	48.33	1.24
176	7.45	0.21	36.58	2.23	8.27	0.18	45.58	2.09
181	7.10	0.15	38.46	1.46	8.17	0.12	52.27	1.42
183	7.15	0.14	40.48	1.49	8.22	0.12	51.47	1.71
192	8.18	0.24	43.48	3.06	8.56	0.22	52.67	3.20
193	8.06	0.22	42.01	2.08	8.36	0.20	49.18	2.76
194	7.15	0.14	36.16	0.80	7.69	0.11	40.94	1.32
203	7.38	0.21	44.16	1.42	7.82	0.12	48.45	1.77
207	7.28	0.14	44.57	1.04	7.59	0.13	47.47	1.97
214	7.01	0.14	42.12	1.20	7.85	0.13	50.49	1.54
215	7.85	0.17	35.78	2.09	8.26	0.15	42.37	2.11
216	7.11	0.14	42.58	1.13	7.92	0.12	51.54	1.42
227	7.31	0.16	39.27	0.89	7.99	0.13	46.11	1.05
230	7.53	0.17	38.40	1.17	8.19	0.16	47.33	1.38
Min	6.98	0.13	33.75	0.80	7.59	0.11	39.13	1.05
Max	8.18	0.46	47.58	6.45	8.70	0.27	56.86	7.37
Mean	7.49	0.20	39.20	1.88	8.13	0.16	46.52	2.11

Appendix II: Chemical properties of surface and sub-surface soils of profile area 2 (Western Dabhalia village)

Polygon ID No.	0-20cm soil				20-40cm soil			
	pH	EC	CEC	ESP	pH	EC	CEC	ESP
	(1:2.5)		(cmol (p ⁺) kg ⁻¹)	%	(1:2.5)		(cmol (p ⁺) kg ⁻¹)	%
3	7.61	0.20	42.87	1.48	7.13	0.12	53.66	1.43
8	7.57	0.13	42.93	1.67	7.63	0.11	54.78	1.49
14	7.51	0.20	41.40	1.13	8.06	0.12	55.78	1.61
15	7.37	0.13	40.79	1.69	7.45	0.15	48.47	1.57
23	7.39	0.16	46.36	1.17	7.45	0.13	51.52	1.45
26	7.42	0.16	48.39	1.23	7.58	0.11	50.43	1.18
35	8.10	0.33	48.57	3.63	7.47	0.12	50.49	1.33
38	7.15	0.15	49.48	1.28	7.43	0.13	51.43	1.26
39	7.25	0.12	50.41	1.11	8.56	0.29	61.20	3.39
41	7.31	0.13	51.66	1.16	7.69	0.10	52.36	0.99
42	7.03	0.19	45.52	1.50	7.71	0.09	54.48	1.13
44	7.01	0.27	46.41	1.18	7.73	0.12	52.83	1.71
46	7.21	0.27	47.54	1.45	7.71	0.10	54.03	1.86
48	7.30	0.14	45.47	1.35	7.93	0.19	54.75	1.71
51	7.29	0.14	44.47	1.41	8.02	0.15	55.05	1.94
131	7.06	0.13	39.67	1.49	7.36	0.12	48.62	1.54
135	7.08	0.13	41.64	1.32	7.41	0.13	49.58	1.15
142	7.35	0.14	46.70	1.82	7.56	0.11	43.57	1.95
169	7.51	0.15	43.52	1.42	8.44	0.11	48.92	2.28
172	7.48	0.15	41.46	1.44	8.22	0.15	53.75	1.02
177	7.04	0.15	36.56	1.59	7.60	0.12	51.43	1.08
226	7.05	0.53	45.10	3.57	8.31	0.31	49.39	3.66
231	7.49	0.29	43.08	3.14	8.46	0.31	50.96	4.56
238	7.65	0.32	44.55	4.20	8.02	0.11	48.29	1.08
243	7.45	0.17	47.98	2.07	7.97	0.12	45.03	1.14
244	7.55	0.20	49.35	1.77	8.17	0.41	49.98	4.64
255	7.59	0.18	43.87	2.24	7.62	0.13	44.25	1.56
Min	7.01	0.12	36.56	1.11	7.13	0.09	43.57	0.99
Max	8.10	0.53	51.66	4.20	8.56	0.41	61.20	4.64
Mean	7.36	0.19	45.03	1.80	7.80	0.15	51.30	1.84

Appendix III: Chemical properties of surface and sub-surface soils of profile area 3 (Eastern part of Butlaw and Dabhalia village)

Polygon ID No.	0-20cm soil				20-40cm soil			
	pH	EC	CEC	ESP	pH	EC	CEC	ESP
	(1:2.5)		(cmol (p ⁺) kg ⁻¹)	%	(1:2.5)		(cmol (p ⁺) kg ⁻¹)	%
Butlaw								
85	7.85	0.17	35.78	2.09	8.26	0.15	42.37	2.11
88	7.31	0.19	38.43	1.13	7.59	0.18	46.22	1.33
89	7.44	0.19	39.49	1.22	7.69	0.18	47.25	1.20
92	7.42	0.21	39.71	1.85	7.73	0.17	52.82	1.76
95	7.38	0.24	38.76	1.81	7.64	0.19	51.50	1.40
97	7.24	0.23	38.61	1.72	7.58	0.18	50.55	1.54
102	7.10	0.20	37.55	1.37	7.39	0.16	44.17	1.44
104	7.24	0.18	39.55	1.01	7.54	0.15	46.13	1.06
109	7.14	0.22	38.49	1.08	7.36	0.19	43.03	1.04
110	7.36	0.13	40.54	1.20	7.45	0.12	44.03	1.23
118	7.18	0.19	37.53	1.37	7.49	0.16	48.41	1.50
119	7.69	0.16	46.55	1.07	8.22	0.14	51.40	1.38
121	7.42	0.15	43.62	0.79	7.86	0.12	48.29	1.24
123	7.38	0.36	48.51	1.23	7.83	0.25	51.95	1.39
125	7.25	0.24	45.39	1.14	7.67	0.20	50.28	1.37
132	7.15	0.13	38.79	1.39	7.56	0.11	47.19	1.14
133	7.42	0.24	42.88	1.39	7.51	0.19	51.60	1.18
166	6.74	0.47	40.50	1.72	7.63	0.12	44.12	1.39
215	7.20	0.14	35.08	0.62	8.06	0.13	43.06	1.39
Dabhalia								
53	7.41	0.22	42.51	1.55	8.22	0.20	47.34	1.48
54	7.35	0.25	44.49	1.46	8.31	0.22	49.26	2.87
58	7.12	0.15	42.33	1.26	7.33	0.12	47.35	1.28
59	7.56	0.14	42.70	1.17	7.69	0.08	51.35	1.07
61	7.65	0.15	45.72	1.08	7.77	0.09	55.61	1.12
64	7.51	0.09	50.68	1.46	7.85	0.08	57.02	1.48
65	7.51	0.10	49.74	1.65	7.69	0.07	55.04	1.75
67	7.47	0.08	49.62	1.41	7.55	0.08	56.02	1.61
70	7.35	0.14	48.72	1.43	7.65	0.10	51.77	1.73
73	7.32	0.12	38.90	1.11	7.67	0.10	44.58	1.21
76	7.48	0.13	50.69	1.16	7.50	0.11	52.59	1.00
83	7.38	0.12	39.94	1.05	7.77	0.08	45.56	1.13
88	7.48	0.20	45.63	1.01	7.91	0.08	49.26	1.19
89	7.10	0.15	40.34	1.26	7.51	0.13	45.72	1.20
92	7.09	0.13	39.43	1.24	7.41	0.10	44.15	1.33
96	7.05	0.11	36.47	1.48	7.31	0.09	45.28	1.41
97	7.17	0.13	43.22	0.80	7.27	0.09	45.99	0.86
98	7.25	0.18	42.42	1.67	7.51	0.16	47.37	1.75
99	6.95	0.22	41.03	1.54	7.71	0.17	49.27	1.27
102	7.04	0.14	42.16	0.75	7.81	0.12	50.54	1.44
103	7.15	0.06	37.36	1.42	7.50	0.07	48.22	1.08
108	7.34	0.17	41.58	1.20	7.56	0.11	47.37	1.19
110	7.45	0.19	42.30	1.17	7.97	0.10	49.31	1.33
112	7.10	0.18	42.51	1.63	7.90	0.16	47.39	1.46
121	6.87	0.17	40.33	1.11	7.75	0.10	48.41	1.40
180	7.21	0.19	41.42	1.28	7.52	0.14	44.19	1.48
185	7.09	0.20	41.84	1.32	7.67	0.15	44.17	1.34
200	7.12	0.15	35.45	1.71	7.39	0.13	42.15	1.58
Min	6.74	0.06	35.08	0.62	7.27	0.07	42.15	0.86
Max	7.85	0.47	50.69	2.09	8.31	0.25	57.02	2.87
Mean	7.29	0.18	41.82	1.31	7.68	0.13	48.23	1.39

**Appendix IV: Available major nutrients, sulphur and micronutrients
of surface soils of profile area 1 (Western Butlaw
village)**

Polygon ID No.	0-20cm soil								
	OC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
	%	Kg ha ⁻¹			mg kg ⁻¹				
5	1.05	234	255	535	24.50	38.56	31.89	7.38	1.17
36	0.65	194	165	375	27.23	17.18	21.70	3.63	0.57
40	0.63	204	160	406	36.20	15.43	22.90	3.83	0.51
47	0.99	245	202	405	20.59	41.02	43.49	8.73	2.12
55	0.99	224	220	419	23.39	40.29	30.05	7.74	2.11
57	0.97	245	214	456	21.99	60.89	23.17	9.43	1.96
58	1.19	255	177	247	31.12	51.03	32.11	7.52	0.85
66	1.08	275	159	273	22.63	69.21	30.01	6.55	0.72
72	1.11	285	222	317	29.94	76.02	30.82	7.87	0.72
80	1.09	296	215	373	28.54	74.92	28.71	6.84	0.68
138	1.17	265	85	786	34.97	36.39	20.49	9.16	0.67
156	1.15	285	228	466	58.95	35.02	20.84	8.12	0.93
161	1.13	296	238	497	55.68	37.13	20.60	7.88	0.92
169	1.50	275	90	216	58.95	42.08	38.81	7.57	0.99
171	1.52	326	101	206	53.81	45.03	39.01	7.78	1.10
176	1.56	326	86	209	64.10	44.08	38.46	7.52	1.03
181	1.01	316	81	284	23.86	34.01	29.47	5.87	0.60
183	1.19	285	317	317	29.65	78.41	38.47	7.27	0.76
192	1.25	316	329	342	21.52	81.19	39.34	7.66	0.81
193	1.25	306	122	265	36.96	47.25	35.01	7.21	0.53
194	1.48	285	142	226	36.96	24.50	33.25	7.19	1.16
203	1.47	275	127	211	36.03	22.07	31.98	6.77	1.01
207	1.53	285	134	217	40.71	24.92	33.75	8.07	1.03
214	1.52	296	247	406	32.75	43.65	20.89	6.21	0.72
215	1.53	275	253	388	29.01	48.51	21.15	7.38	0.89
216	1.60	265	274	404	55.68	67.46	41.31	7.79	0.63
227	1.48	275	144	286	23.86	41.69	35.17	8.07	1.07
230	1.65	316	87	253	51.00	78.06	28.64	11.35	1.03
Min	0.63	194	81	206	20.59	15.43	20.49	3.63	0.51
Max	1.65	326	329	786	64.10	81.19	43.49	11.35	2.12
Mean	1.24	276	181	349	36.09	47.00	30.77	7.44	0.98

**Appendix V: Available major nutrients, sulphur and micronutrients
of sub-surface soils of profile area 1 (Western Butlaw
village)**

Polygon ID No.	20-40cm soil								
	OC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
	%	Kg ha ⁻¹			mg kg ⁻¹				
5	0.94	163	197	402	21.23	28.37	28.13	5.50	0.92
36	0.44	102	109	285	19.39	16.14	17.93	2.65	0.47
40	0.43	92	98	244	28.25	11.37	18.97	2.98	0.43
47	0.60	112	153	379	10.76	35.97	30.27	4.60	1.75
55	0.61	122	171	243	15.44	35.57	18.28	4.12	1.46
57	0.59	102	163	441	13.57	48.29	18.84	4.47	1.64
58	0.83	132	115	209	25.27	32.14	14.19	4.57	0.69
66	0.81	122	111	240	21.52	57.85	13.88	5.15	0.65
72	0.84	122	169	245	28.54	69.72	14.10	5.47	0.63
80	0.83	132	164	266	27.14	66.33	13.03	5.03	0.57
138	0.96	71	60	530	23.10	32.77	15.61	4.19	0.38
156	1.01	122	167	375	30.12	32.09	15.38	5.71	0.76
161	1.00	92	213	396	38.25	35.92	19.23	5.55	0.65
169	1.04	153	67	171	34.15	38.57	23.79	4.73	0.80
171	1.04	153	87	164	37.91	35.79	23.74	7.00	0.84
176	1.07	143	83	185	47.72	30.11	22.84	6.92	0.75
181	0.69	112	59	204	14.04	31.02	22.72	4.46	0.54
183	0.73	112	157	169	20.76	66.87	19.56	5.56	0.74
192	0.77	122	176	185	16.38	73.69	21.16	6.99	0.77
193	0.59	112	83	191	29.48	36.88	26.51	4.12	0.43
194	0.77	122	88	191	21.99	20.05	25.17	3.96	0.86
203	0.74	112	69	149	21.52	17.89	23.38	3.03	0.80
207	0.83	92	74	209	24.80	18.92	28.65	3.54	0.81
214	1.14	132	159	326	21.99	34.21	13.94	5.26	0.62
215	1.17	122	189	295	27.60	35.29	14.84	5.78	0.62
216	1.10	143	130	202	39.77	51.03	13.29	6.52	0.74
227	0.76	102	67	240	18.72	32.77	16.90	4.29	0.75
230	1.27	143	64	230	30.41	61.10	32.26	6.62	0.65
Min	0.43	71	59	149	10.76	11.37	13.03	2.65	0.38
Max	1.27	163	213	530	47.72	73.69	32.26	7.00	1.75
Mean	0.84	120	123	263	25.35	38.81	20.24	4.96	0.78

**Appendix VI: Available major nutrients, sulphur and micronutrients
of surface soils of profile area 2 (Western Dabhalia
village)**

Polygon ID No.	0-20cm soil								
	OC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
	%	Kg ha ⁻¹			mg kg ⁻¹				
3	0.69	194	39	451	18.25	50.27	16.77	3.21	0.80
8	0.58	194	44	483	17.78	56.02	17.55	3.07	0.83
14	0.73	245	104	250	17.76	43.98	34.84	10.80	1.29
15	0.59	194	39	473	17.31	55.51	17.82	7.01	0.80
23	1.31	275	125	258	19.18	72.11	24.78	8.41	1.33
26	1.32	285	130	268	21.52	74.92	25.45	8.75	1.36
35	1.20	234	171	222	47.26	62.24	36.93	11.08	0.74
38	1.00	224	146	346	15.44	35.58	32.52	7.66	1.10
39	1.00	224	115	270	18.25	49.20	32.00	7.97	0.91
41	0.99	214	122	274	23.39	48.46	23.58	9.71	0.85
42	0.96	204	129	244	46.79	72.30	32.70	6.07	1.25
44	0.97	214	237	235	62.99	80.89	25.50	5.88	1.28
46	0.96	204	192	255	52.40	74.60	36.00	5.55	1.07
48	0.96	204	159	246	19.83	65.97	39.39	8.89	1.16
51	0.97	204	157	240	12.63	62.30	38.40	8.97	1.13
131	0.99	214	214	609	46.79	47.90	29.02	12.87	2.74
135	1.23	265	221	642	44.45	56.80	31.34	12.72	2.55
142	1.07	204	284	296	40.18	33.65	32.50	8.27	2.10
169	1.04	204	111	289	22.93	54.06	31.89	12.84	1.06
172	1.08	275	109	303	19.18	53.30	32.27	14.08	1.16
177	0.96	234	165	288	26.20	60.10	39.97	9.84	1.59
226	1.69	296	138	331	120.06	48.20	30.02	14.49	1.34
231	0.97	204	167	280	55.68	29.01	35.87	9.48	1.15
238	0.87	194	185	318	53.81	30.20	37.64	9.84	0.81
243	0.99	214	269	293	21.99	32.85	32.40	7.64	2.16
244	1.07	204	216	311	25.80	33.89	32.00	8.20	2.32
255	0.97	204	291	298	47.67	34.02	29.90	7.83	2.25
Min	0.58	194	39	222	12.63	29.01	16.77	3.07	0.74
Max	1.69	296	291	642	120.06	80.89	39.97	14.49	2.74
Mean	1.01	223	159	325	34.65	52.53	30.71	8.93	1.37

**Appendix VII: Available major nutrients, sulphur and micronutrients
of sub-surface soils of profile area 2 (Western Dabhalia
village)**

Polygon ID No.	20-40cm soil								
	OC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
	%	Kg ha ⁻¹			mg kg ⁻¹				
3	0.96	153	70	315	10.29	29.16	26.30	7.25	0.72
8	0.74	132	80	228	14.04	33.50	22.70	5.19	0.53
14	0.73	143	67	248	15.73	31.90	16.22	5.33	0.61
15	0.76	173	81	223	38.83	55.10	22.40	5.05	0.93
23	0.77	163	132	228	40.24	65.50	19.60	4.97	0.93
26	0.80	183	145	209	38.83	69.10	17.20	4.02	0.76
35	0.96	163	73	217	9.83	54.30	31.90	7.87	0.81
38	0.96	173	95	244	17.02	54.53	31.67	7.79	0.91
39	0.74	122	65	199	36.84	56.88	22.44	4.65	0.41
41	0.80	143	76	229	8.89	63.02	20.11	4.18	0.91
42	0.81	153	64	223	10.76	68.96	20.05	4.24	0.96
44	1.04	173	259	265	36.03	29.01	18.70	6.21	1.58
46	0.93	163	187	269	11.70	30.11	19.81	6.45	1.76
48	1.04	183	171	291	13.57	28.37	18.07	5.96	1.42
51	0.84	153	249	259	38.72	29.01	17.67	6.95	1.59
131	0.83	153	162	366	34.80	43.20	28.30	7.39	1.77
135	0.84	183	159	379	33.39	48.51	24.13	7.73	1.56
142	0.46	82	31	331	9.83	46.91	13.80	5.73	0.72
169	0.44	71	30	345	12.16	39.87	13.16	2.52	0.49
172	0.46	82	29	334	10.76	43.12	13.99	2.45	0.79
177	0.79	143	73	233	9.29	35.92	31.62	7.27	1.10
226	0.76	153	106	257	49.59	27.81	27.96	7.71	0.82
231	0.74	173	116	285	45.85	23.33	19.87	6.06	0.49
238	0.91	112	87	274	14.50	48.76	20.76	9.55	1.39
243	0.93	143	91	239	15.42	44.10	21.75	8.94	0.92
244	1.07	204	95	248	108.84	32.77	26.20	7.73	0.78
255	0.94	122	120	241	24.80	54.80	33.94	8.57	1.22
Min	0.44	71	29	199	8.89	23.33	13.16	2.45	0.41
Max	1.07	204	259	379	108.84	69.10	33.94	9.55	1.77
Mean	0.82	148	108	266	26.32	43.98	22.23	6.21	1.00

Appendix VIII: Available major nutrients, sulphur and micronutrients of surface soils of profile area 3 (Eastern part of Butlaw and Dabhalia village)

Polygon ID No.	0-20cm soil								
	OC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
	%	Kg ha ⁻¹			mg kg ⁻¹				
Butlaw									
85	1.01	316	81	284	23.86	34.01	29.47	5.87	0.60
88	0.84	255	145	272	67.84	47.51	31.87	6.68	0.89
89	0.81	245	140	385	72.52	48.56	31.67	7.25	0.79
92	0.95	255	132	291	24.33	74.25	38.09	6.34	0.79
95	1.00	275	141	298	26.67	76.67	39.78	7.38	0.80
97	0.97	255	144	311	27.60	63.95	38.42	6.74	0.57
102	1.28	265	157	386	21.99	76.52	40.82	5.53	1.65
104	1.32	275	147	393	23.39	86.02	42.83	5.78	1.89
109	1.35	285	150	384	22.93	85.73	42.52	5.61	2.03
110	1.69	306	307	374	36.96	127.70	24.13	11.21	2.41
118	0.99	275	145	326	28.07	77.05	40.88	8.33	0.90
119	1.48	265	247	467	21.70	29.84	24.05	5.00	0.86
121	1.57	285	255	497	23.57	32.08	26.65	5.94	1.01
123	1.87	326	161	373	88.49	60.26	28.93	10.79	1.04
125	1.53	285	158	279	69.13	61.08	30.82	11.00	1.10
132	1.60	285	224	258	16.84	92.83	36.71	7.52	0.87
133	1.85	285	58	875	71.24	87.80	32.79	16.36	1.01
166	1.60	326	156	401	25.27	73.18	36.49	10.89	1.12
215	1.33	234	113	249	35.09	66.47	34.19	7.11	0.50
Dabhalia									
53	0.99	224	169	280	35.56	47.10	32.91	8.37	0.83
54	1.01	234	176	281	37.90	46.32	22.92	8.34	0.80
58	0.95	214	171	257	33.57	58.60	46.00	9.01	1.08
59	0.80	194	172	468	14.50	53.20	38.40	6.86	1.55
61	0.79	194	165	484	15.44	54.53	28.13	6.56	1.52
64	0.96	204	183	243	84.21	58.17	24.41	7.15	1.74
65	0.95	214	211	240	74.46	49.51	35.01	7.77	1.94
67	0.96	204	190	371	37.95	59.25	27.97	8.07	1.18
70	1.09	214	229	473	28.21	59.68	27.59	5.97	1.13
73	0.69	204	39	685	19.36	38.20	23.21	9.34	1.57
76	1.19	224	321	529	21.99	65.97	28.49	7.12	1.15
83	0.72	214	47	860	17.29	37.86	23.53	9.84	1.54
88	0.80	224	158	448	26.34	22.99	24.90	6.02	1.80
89	1.00	183	103	253	27.99	49.85	32.32	11.35	1.29
92	0.88	204	110	216	23.39	46.68	30.82	13.05	1.35
96	1.01	224	325	280	12.16	49.63	40.92	9.97	1.87
97	1.04	224	294	333	18.89	51.03	28.27	7.63	1.11
98	0.93	204	127	257	53.81	48.82	26.99	9.04	1.29
99	0.95	234	115	299	59.42	47.21	23.12	6.84	1.40
102	1.05	255	276	290	27.95	52.04	26.74	7.79	1.01
103	1.03	265	245	255	17.49	56.20	46.32	9.30	1.90
108	0.85	194	149	429	24.68	22.85	27.51	6.87	1.94
110	0.80	173	113	202	34.68	40.60	22.47	7.11	1.69
112	0.96	173	111	250	37.43	69.70	33.01	11.49	1.06
121	0.95	224	212	303	43.51	55.50	27.22	13.95	1.28
180	0.91	194	144	297	51.00	49.32	29.81	9.04	1.09
185	0.92	224	137	278	49.59	53.93	27.72	8.07	1.05
200	0.97	194	159	318	28.07	58.62	42.82	8.75	1.33
Min	0.69	173	39	202	12.16	22.85	22.47	5.00	0.50
Max	1.87	326	325	875	88.49	127.70	46.32	16.36	2.41
Mean	1.09	239	168	361	35.84	57.55	31.93	8.34	1.26

**Appendix IX: Available major nutrients, sulphur and micronutrients
of sub-surface soils of profile area 3 (Eastern part of
Butlaw and Dabhalia village)**

Polygon ID No.	20-40cm soil								
	OC	N	P ₂ O ₅	K ₂ O	S	Fe	Mn	Cu	Zn
	%	Kg ha ⁻¹			mg kg ⁻¹				
Butlaw									
85	0.69	112	59	204	14.04	31.02	22.72	4.46	0.54
88	0.76	112	133	190	43.98	39.28	29.54	5.91	0.44
89	0.74	92	130	276	53.34	37.32	27.36	5.59	0.43
92	0.76	122	98	199	16.38	64.98	22.73	5.22	0.55
95	0.79	92	136	204	25.73	68.02	24.39	6.90	0.78
97	0.77	112	138	224	22.93	56.87	25.26	4.86	0.48
102	0.87	122	127	321	17.91	68.57	29.65	2.55	0.86
104	0.90	132	119	284	20.12	71.01	32.76	2.94	1.08
109	0.91	132	126	261	19.18	69.91	32.01	2.64	1.89
110	1.44	194	259	360	31.82	110.80	12.13	10.43	2.24
118	0.77	112	102	225	27.60	69.57	26.27	7.56	0.66
119	0.71	102	144	332	20.29	15.21	14.27	4.20	0.43
121	0.74	112	139	366	14.04	17.25	16.01	4.64	0.94
123	1.59	183	126	293	72.99	50.40	19.36	10.06	1.01
125	1.14	153	119	232	55.03	56.03	22.75	8.69	0.84
132	0.91	132	180	243	14.50	74.95	31.71	6.66	0.70
133	1.50	173	50	664	55.21	74.32	23.87	14.63	0.69
166	1.23	183	102	296	17.31	59.98	24.65	9.78	0.69
215	0.54	102	38	217	26.20	40.18	25.42	3.73	0.36
Dabhalia									
53	0.76	153	57	257	23.57	23.71	18.32	4.77	0.43
54	0.73	143	64	269	14.50	23.69	17.31	4.65	0.40
58	0.90	173	83	230	17.95	43.20	31.70	7.77	0.85
59	0.79	132	102	230	8.89	33.10	22.30	4.87	0.80
61	0.76	153	134	232	11.23	33.39	21.81	4.79	0.78
64	0.76	132	71	216	73.92	43.24	21.76	5.18	0.94
65	0.74	163	91	202	52.00	42.70	32.38	5.23	1.03
67	0.79	153	89	276	15.15	54.53	22.02	5.61	0.67
70	0.83	183	181	369	18.14	55.65	21.91	5.35	1.09
73	0.69	132	28	555	14.68	28.10	17.79	6.64	0.95
76	0.99	183	256	407	13.10	60.75	22.35	6.43	1.19
83	0.69	132	24	615	13.74	29.26	14.29	5.87	0.82
88	0.66	204	63	304	21.34	17.67	16.52	3.82	1.32
89	0.97	183	88	233	25.73	45.36	32.13	9.88	0.88
92	0.70	143	87	205	21.99	41.07	28.28	9.31	0.99
96	0.84	163	228	258	9.83	38.25	36.23	8.01	1.46
97	0.96	173	267	287	17.95	43.02	22.75	5.73	0.93
98	0.90	153	79	231	32.75	43.02	20.78	6.67	1.14
99	0.93	153	81	271	44.62	36.55	18.95	5.50	1.02
102	1.00	163	246	265	18.89	47.08	20.52	7.17	0.98
103	0.83	173	174	240	9.49	55.43	32.39	6.34	1.07
108	0.67	122	84	284	13.24	16.92	24.27	5.22	1.51
110	0.77	143	91	218	21.87	30.25	13.16	5.68	0.96
112	0.93	183	102	263	24.80	50.40	31.10	8.76	0.83
121	0.74	132	115	257	33.86	44.10	20.26	6.24	0.96
180	0.79	132	113	244	37.90	46.18	26.85	6.42	0.98
185	0.80	132	103	255	39.77	45.81	23.91	6.71	0.83
200	0.93	143	108	240	19.18	53.02	35.26	6.70	1.19
Min	0.54	92	24	190	8.89	15.21	12.13	2.55	0.36
Max	1.59	204	267	664	73.92	110.80	36.23	14.63	2.24
Mean	0.86	145	118	283	26.36	46.83	24.05	6.31	0.91



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